United States
Department of
Agriculture

Agricultural
Research
Service

Northern
Plains Area

Natural Resources Research Center

1994 Report

For Additional Information:

James R. Welsh, NRRC Director
Crops Research Laboratory
1701 Center Avenue
Fort Collins, CO 80526

TEL: (970) 498-4227
FAX: (970) 498-4242
FTS2000: a03dirnrrcfc
INTERNET: jwelsh@lamar.colostate.edu

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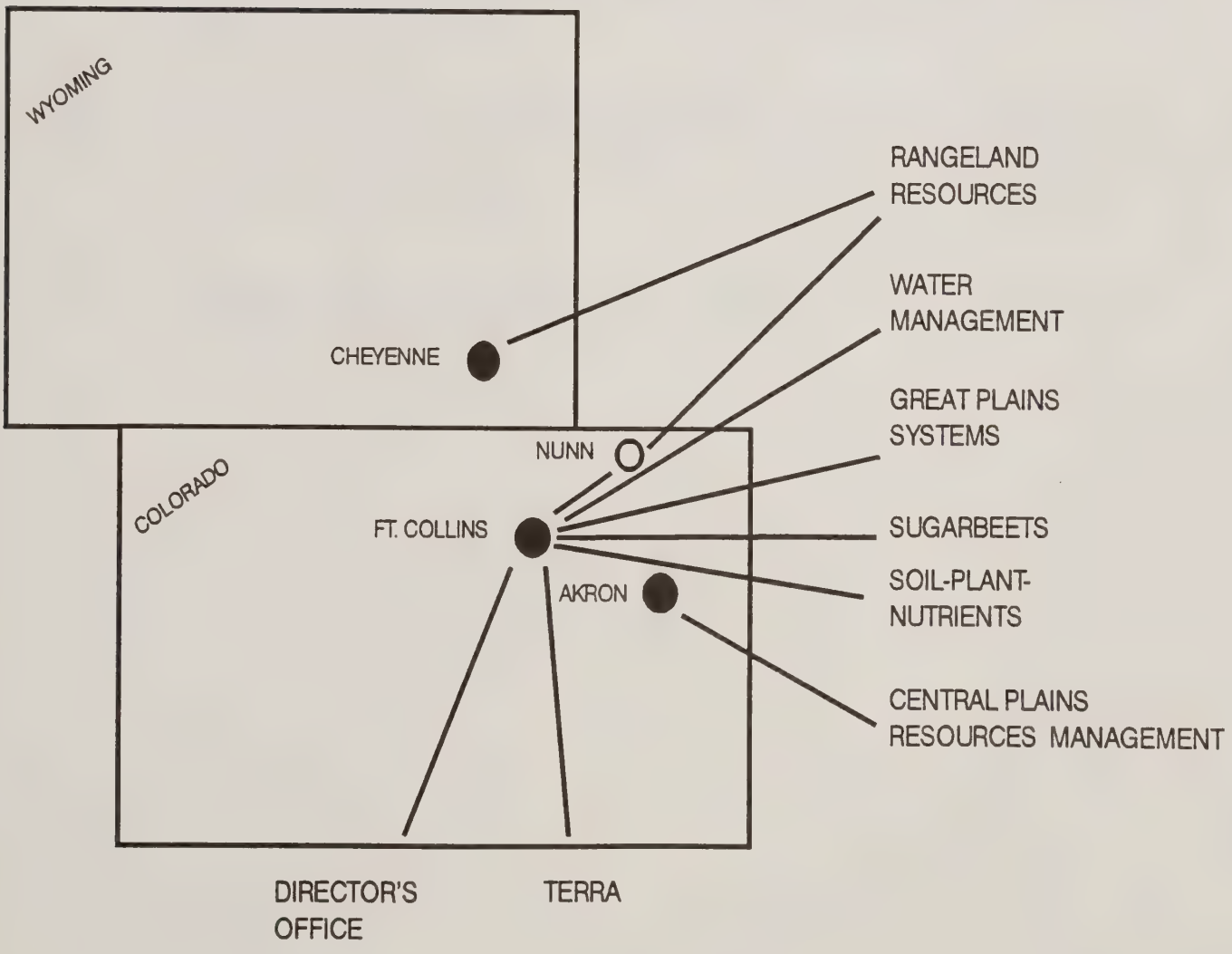

Introduction

Background

The Natural Resources Research Center is a coordinated structure of research units with strong emphasis on quality products and customer satisfaction. This report summarizes Center research production for CY 1994. Material is arranged by research unit with appropriate contact information to encourage information exchange and cooperation across the total scientific community. The scientific publications, presentations, awards and recognitions, technology transfer and emerging partnerships with public and private sector organizations demonstrate outstanding performance by Center research scientists and staff.

This year has been one of emerging issues related to agriculture. In particular, environmental concerns and natural resource protection have received increasing national priority and attention. The NRRC recognizes this trend, primarily through interaction with customers from all backgrounds of life. In response, program thrusts are continually being updated to address both contemporary and forward looking societal needs.

Total Quality Management

The Center has embraced Total Quality Management as a way of conducting daily business. 1994 was a year of growth and learning in TQM. The Center has launched a major thrust of TQM application to production of research products for external customer satisfaction.

Thank You

We hope you will find this report valuable. You are encouraged to contact any of the NRRC scientists and staff for further information.

James Welsh, Center Director
Olga Lee, Secretary
Dave Noroski, Utility Sys Operator

NRRC Staff - 1994

Steve Rapp, Custodial Maintenance
Oliver Mayhan, Prev. Maint. Tech.
Jeff Johnson, Custodial Assist.

	Central Plains Resources Management	Great Plains Systems Research	Rangeland Resources Research Unit	Soil-Plant-Nutrient Research Unit	Sugarbeet Research Unit	Terrestrial Ecosystems Regional Research and	Water Management Research Unit
Research Scientists	Randy Anderson Rudy Bowman David Nielsen Merle Vigil	Lajpat Ahuja, RL Jim Ascough II Jon Hanson Gregory McMaster Marvin Shaffer Lori Wiles	Gerald Schuman, RL Terrance Booth Gary Frasier Richard Hart Jack Morgan Charley Townsend	Ronald Follett, RL William Hunter Gordon Hutchinson Arvin Mosier Lynn Porter	Earl Ruppel, RL Susan Martin Leonard Panella	Donn DeCoursey Brenda Faber Doug Fox Tom Goonan Gene Kersey Ray Watts Bob Woodmansee	Dale Heermann-RL Walter Bausch Gerald Buchleiter Harold Duke Edward Schweizer Roger Smith
Support Scientists	Curtis Reule	Patricia Bartling Mary Brodahl Gale Dunn Virginia Ferreira Harriet Havis	Daniel LeCain Jean Reeder Ernest Taylor	Robert Lober William O'Deen	Andrew Lenssen	Virginia Ferreira Bill Wallace	Richard Miskimins Kristine Stahll
Post Docs		Robert Aiken Joseph Benjamin Howard Skinner	John Reed	Jorge Delgado Peter Scharf			M. Scott Howarth Lori Wiles
Research Support Staff	Lynne Bixler Carolyn Brandon Katie Drullinger Robert Florian Donna Fritzler Stephanie Hill Marrietta Koch Hubert Lagae Gene Uhler Dee Webb	William Dailey Debora Edmunds Michael Murphy Kenneth Rojas Lucretia Sherrod	Willard Ackerman Mary Ashby Leon Chea Stanley Clapp Pamela Freeman Larry Griffith Roger Kerbs Chris Mahelona Matt Mortenson Dennis Mueller James Pry Jeffrey Thomas Barry Weaver	Charles Andre Edward Buenger Susan Crookall Cathy Krumwiede Margarita Licha Robin Montenieri Elizabeth Pruessner Mary Smith	Mary Hjort Mary McClintock Patricia Noble Les Shader Johnny Thomas John Vasquez	Saneta Gavette Nicole Haynes Simon Lee Jeffery Lundstrom Sandy Maple Jeff Miller	Douglass Barlin Ted Bernard Michael Blue Daryl Carr Mark Collins Dean Santistevan

	Central Plains Resources Management	Great Plains Systems Research	Rangeland Resources Research Unit	Soil-Plant-Nutrient Research Unit	Sugarbeet Research Unit	Terrestrial Ecosystems Regional Research and	Water Management Research Unit
Administrative Support Staff	Ginger Allen Llewellyn Bass Linda Pieper	Julie Leppert Marlene Miller Harry Spokes	Marcella Currie-Gross Ann Heckart Pam Kerbs Kathleen Peterson	Stacey Wilkins	Marcella Currie-Gross	Vacant	Maxine McCauley Lynne Paschal
Visiting Scientists/ Cooperative Staff	Mahdi Al Kaisi Scott Armstrong Mike Koch	Claudio Dunan Rob Erskine Hamid Farrahani Fritz Fiedler Maurice Hall Karen Johnsen Daniel Palic Rick Proctor Steve Stadelmeier Karen Stonaker Bruce Vandenberg		Gerald Livingston Eldor Paul Mary Scholes			

AWARDS AND RECOGNITION - 1994

Employee	Award(s)/Recognition Received
Charles Andre	• Certificate of Appreciation - *for the Soil-Plant-Nutrient Research Unit Renovation TQM Team* - for 'Outstanding service to the Soil-Plant-Nutrient Research Unit and to the ARS to minimize construction impacts upon Unit personnel and research programs • Certificate of Merit - Cash Award for 'Exceptional service to the Soil-Plant-Nutrient Research Unit and to ARS in facilitating chiller system and HVAC renovation
Pat Bartling	• USDA-ARS, Certificate of Appreciation "for developing a more efficient procedure for tracking purchasing requests and preparing the purchasing handbook for the unit staff
Walter Bausch	• Ten-year service pin USDA-ARS • Program Chair-International Evapotranspiration and Irrigation Scheduling Conference, 1996 • Chair/Past Chair-ASAE SW-213 (Evapotranspiration Committee)
Joseph Benjamin	• Editors' Citation for Excellence in Manuscript Review, Soil Society of America Journal, 1994
Michael Blue	• National Federal Water and Energy Award for Exemplary Sustained Service for Water Conservation. (DOE)
Gerald Buchleiter	• National Federal Water and Energy Award for Exemplary Sustained Service for Water Conservation. (DOE)
Edward Buenger	• Certificate of Appreciation - *for the Soil-Plant-Nutrient Research Unit TQM Team* - for 'Outstanding service in establishing an action plan for TQM in the Soil-Plant-Nutrient Research Unit, successful achievement of their stated mission to improve communication, and enhancement of overall cooperation within the Research Unit • Certificate of Appreciation - *for the Soil-Plant-Nutrient Research Unit Renovation TQM Team* - for 'Outstanding service to the Soil-Plant-Nutrient Research Unit and to the ARS to minimize construction impacts upon Unit personnel and research programs

Employee	Award(s)/Recognition Received
Susan Crookall	• Certificate of Appreciation - *for the Soil-Plant-Nutrient Research Unit Renovation TQM Team* - for 'Outstanding service to the Soil-Plant-Nutrient Research Unit and to the ARS to minimize construction impacts upon Unit personnel and research programs • Certificate of Appreciation - *for the Soil-Plant-Nutrient Research Unit TQM Team* - for 'Outstanding service in establishing an action plan for TQM in the Soil-Plant-Nutrient Research Unit, successful achievement of their stated mission to improve communication, and enhancement of overall cooperation within the Research Unit • Certificate of Appreciation - for 'Sustained outstanding performance as the Soil-Plant-Nutrient Research Unit Safety Officer and Chairperson of the Fort Collines ARS Safety Committee
Harold Duke	• Chairperson-ASAE P511 Refereed Publications Committee • NPA, SPA, WMA Patent Advisory Committee • National Federal Water and Energy Award for Exemplary Sustained Service for Water Conservation. (DOE)
Debbie Edmunds	• USDA-ARS, Certificate of Appreciation "for developing a more efficient procedure for tracking purchasing requests and preparing the purchasing handbook for the unit staff
Brenda Faber	• Invited to present a workshop on ARGIS at the Urban and Regional Information Systems Assoc. (URISA) and received an award as Best Overall Project
Gary Frasier	• President's Citation - for his leadership and enthusiasm in organizing the recently formed Rocky Mountain section, American Society of Agricultural Engineers
Pam Freeman	• For outstanding efforts in cleaning and maintaining operation of the laboratory at the High Plains Grasslands Research Station during recent severe sewage system problems
Richard Hart	• Selected Fellow of American Society of Agronomy
Dale Heermann	• Thirty-year Service Award USDA-ARS • Chairperson-ASAE E10/3 Market Emphasis Committee • Chairperson-IA Awards Committee • Cochairperson-IA Research Committee • National RPES Advisory Committee • Member National Academy of Science, WSTB Study Committee on Future of Irrigation in the Face of Competing Demands • National Federal Water and Energy Award for Exemplary Sustained Service for Water Conservation. (DOE)
Gordon Hutchinson	• Elected Fellow of the ASA and SSSA

Employee	Award(s)/Recognition Received
Olga Lee	• For exceptional professional commitment in exceeding the highest performance standard expectations, and continued application of Total Quality Management principles in meeting customer needs
Robert Lober	• Certificate of Appreciation - *for the Soil-Plant-Nutrient Research Unit Renovation TQM Team* - for 'Outstanding service to the Soil-Plant-Nutrient Research Unit and to the ARS to minimize construction impacts upon Unit personnel and research programs • Certificate of Appreciation - *for the Soil-Plant-Nutrient Research Unit TQM Team* - for 'Outstanding service in establishing an action plan for TQM in the Soil-Plant-Nutrient Research Unit, successful achievement of their stated mission to improve communication, and enhancement of overall cooperation within the Research Unit
Chris Mahelona	• For outstanding efforts in cleaning and maintaining operation of the laboratory at the High Plains Grasslands Research Station during recent severe sewage system problems
Jack Morgan	• Certificate of Appreciation for service on the Crops Research Laboratory TQM Team
Matt Mortenson	• For exceptional initiative and talent in repairing the atomic absorption spectrophotomer resulting in a substantial savings
Lynn Porter	• Certificate of Appreciation - *for the Soil-Plant-Nutrient Research Unit TQM Team* - for 'Outstanding service in establishing an action plan for TQM in the Soil-Plant-Nutrient Research Unit, successful achievement of their stated mission to improve communication, and enhancement of overall cooperation within the Research Unit • Certificate of Appreciation - *for the Soil-Plant-Nutrient Research Unit Renovation TQM Team* - for 'Outstanding service to the Soil-Plant-Nutrient Research Unit and to the ARS to minimize construction impacts upon Unit personnel and research programs
Elizabeth Pruessner	• Certificate of Appreciation - *for the Soil-Plant-Nutrient Research Unit TQM Team* - for 'Outstanding service in establishing an action plan for TQM in the Soil-Plant-Nutrient Research Unit, successful achievement of their stated mission to improve communication, and enhancement of overall cooperation within the Research Unit • Certificate of Appreciation - *for the Soil-Plant-Nutrient Research Unit Renovation TQM Team* - for 'Outstanding service to the Soil-Plant-Nutrient Research Unit and to the ARS to minimize construction impacts upon Unit personnel and research programs
Jim Pry	• For outstanding efforts in cleaning and maintaining operation of the laboratory at the High Plains Grasslands Research Station during recent severe sewage system problems

Employee	Award(s)/Recognition Received
Edward Schweizer	• Chairperson-Fellows & Honorary Member Awards Committee, Weed Science Society of America • Chairperson-Outstanding Weed Scientist Awards Committee, Western Society of Weed Science
Marvin Shaffer	• USDA-ARS, Certificate of Appreciation "for continued exceptional efforts in the transfer of NLEAP technology to SCS and other customers" • USDA-ARS, letter of appreciation from theAdministrator of SCS for technology transfer of NLEAP to SCS
Roger Smith	• Editorial Board, Ecological Modelling, Elsevier Sciences • Editorial Board, Geographical Abstracts-Physical Geography, Elsevier Sciences
Ernest Taylor	• For outstanding efforts in cleaning and maintaining operation of the laboratory at the High Plains Grasslands Research Station during recent severe sewage system problems
Bill Wallace	• Invited to present a workshop on ARGIS at the Urban and Regional Information Systems Assoc. (URISA) and received an award as Best Overall Project
Lori Wiles	• Recipient of Outstanding Paper published in Vol.43, WEED SCIENCE IN 1993
Stacey Wilkins	• Certificate of Appreciation - *for the Soil-Plant-Nutrient Research Unit TQM Team* - for 'Outstanding service in establishing an action plan for TQM in the Soil-Plant-Nutrient Research Unit, successful achievement of their stated mission to improve communication, and enhancement of overall cooperation within the Research Unit

PROGRESS REPORTS

NATURAL RESOURCES RESEARCH CENTER

James R. Welsh, Center Director
Crops Research Laboratory
1701 Center Avenue
Fort Collins, CO 80526
TEL: (970) 498-4227
FAX: (970) 498-4242

FTS2000: a03dirnrrcfc@attmail.com
INTERNET: jwelsh@lamar.colostate.edu

MISSION STATEMENT

Promote and coordinate cooperative research activities among Center research units; serve as an advocate and solicit funding and support for priority research efforts identified by Center units and ARS; and facilitate communications and interaction among research programs and with customers locally, regionally and nationally.

TECHNOLOGY TRANSFER - 1994

Natural Resources Research Center

1. Development and utilization of customer focus groups for various research units throughout the NRRC is a top priority activity. Customers provide valuable information about products needed. In addition, they provide critical input into product quality and usability. For example, the development of the decision support program GPFARM relies heavily on customer input in designing a usable product. Customer focus groups are currently active in four research units

2. The Center provides an important link to other agencies and organizations. These include the Great Plains Agriculture Council, Colorado State University, the Sustainable Agriculture program, the Colorado Department of Agriculture, the Soil Conservation Service, the Irrigation Association and the Colorado Conservation Tillage Association. The NRRC represents all unit programs in these contacts. Ideas and advice on program priorities and direction are actively solicited.

3. A satellite based wetlands conference is being developed in partnership with CSU, NRCS, EPA and several other agencies. Utilizing communications capabilities at CSU, the conference will be down-linked to 30 locations throughout Colorado.

4. DTN continues to increase in information capabilities. The NRRC actively supports this satellite based program which now has several thousand producer subscribers throughout the central Great Plains. Future plans include the production of programs such as cropping system alternatives and residue management utilizing information developed by NRRC research units.

NRRC PROGRESS REPORT

Author(s)

James R. Welsh

Background

The Natural Resources Research Center (NRRC) Director's Office promotes and coordinates research activities between individuals and Units within the NRRC, the Agricultural Research Service (ARS), and other public agencies and institutions. A critical part of the coordination activity rests with the Board of Directors for the Center made up of Unit Research Leaders (RLs). Through its monthly meetings, the Board considers issues and programs to receive attention throughout the year. The following items summarize NRRC projects and activities for 1994:

Program Planning and Coordination

The NRRC set the stage for a major program review scheduled for early 1995. The review will emphasize program thrusts cutting across research units. An outstanding review team involving research scientists, Universities, private industry, other agencies and individual producers has been assembled. The review will emphasize customer oriented futuristic planning appropriate to the nations needs in the next century.

The Great Plains Framework for Agricultural Resource Management (GPFARM) decision support system project obtained a program coordinator and is continuing to involve scientists across research units and CSU. A customer focus group has been established to provide input on expected products. The Nitrogen Management and Groundwater Quality team of NRRC and CSU scientists have been successful in securing outside resources to support their joint efforts. The Water Research unit has worked closely with CSU in developing the new Agricultural Research and Development Center (ARDEC) and establishing irrigation research near the campus. A highly successful symposium was held jointly with the CSU Long Term Ecological Research (LTER) team. The symposium focused on research being conducted on the Central Plains Experimental Range (CPER).

The ARS/SCS Research Committee made up of Colorado NRCS program leaders and NRRC Research Leaders identified high-priority research needed to meet farm plan and grower requirements. Research programs were developed to answer several high-priority questions. The Committee meets twice annually to review current activities and future research priority needs. The NRRC is cooperating and co-sponsoring a satellite based information program on wetlands to be delivered to customers at 30 locations in early 1995.

A joint workshop on cropping systems and residue management was organized by NRRC scientists in cooperation with the Brookings ARS laboratory and three Universities. It accomplished the purpose of increasing dialog among researchers and setting the stage for future program planning.

Customer Focus Groups

Customer focus groups are actively involved in the Water Research, Range Research, Central Plains Research, Great Plains Systems Research and Sugarbeet Research Units.

They provide valuable insight into priority research areas and assist in product evaluation.

Total Quality Management

An NRRC all-events day was organized by the TQM Council to increase program awareness throughout the Center. Training programs and workshops were provided in facilitation, E-mail, writing style and quality, and the relationship between TQM and research. TQM teams addressed issues of purchasing, newsletter, and resource inventory. A graphics team and an Internet training team have been formed. TQM continues to form the basis for program management and delivery. NRRC personnel served on area and national reinvention teams to improve management and research output and rewards. The NRRC Director co-chaired an ARS team to recommend implementation strategies for the Government Performance and Results Act (GPRA).

Communication

The NRRC now has 130 individual computers networked on Internet through CSU. E-mail is the main method of distributing information in lieu of hard copy. We continue to work toward a paper-free office environment.

CENTRAL PLAINS RESOURCES MANAGEMENT RESEARCH UNIT

Randy L. Anderson, Acting Research Leader
Central Great Plains Research Station
40335 County Road GG
P.O. Box 400
Akron, CO 80720
TEL: (970) 345-2259
FAX: (970) 345-2088

FTS2000: a03lcakron@attmail.com
INTERNET: lcakron@lamar.colostate.edu

MISSION STATEMENT

To enhance the economic and environmental well-being of agriculture by development of integrated cropping systems and technologies for maximum utilization of soil and water resources. Emphasis is on efficient use of plant nutrients, pesticides, and water and soil conservation/preservation.

TECHNOLOGY TRANSFER - 1994

Central Plains Resources Management Research Unit

The staff participated in technology transfer by:

1. Sponsoring a Station Field Day on June 22, 1994. Approximately 200 producers, agricultural business representatives, USDA-SCS personnel, and CSU scientists attended.

2. Co-sponsoring an equipment field day with the Colorado Conservation Tillage Association on June 22, 1994. Approximately 75 producers attended.

3. Interacting with the USDA-SCS by serving on the SCS research and residue management committees, and writing fact sheets on residue degradation and control strategies for winter annual grasses in winter wheat.

4. Serving on management teams for the Technology Resource Integrated Management (TRIM) program which is enhancing technology transfer to producers.

5. Serving on the Board of Directors for the Colorado Conservation Tillage Association, and participating in their annual winter meeting, where the staff presented information on legumes, corn, residue management, and moisture conservation.

6. Organizing a cropping systems workshop for the Great Plains region, which focused on long-range planning in cropping systems research.

7. Sponsoring the Maximum Economic Yield (MEY) Club at Akron, where bi-monthly meetings are held each winter. Staff presents research data to producers on cropping systems, alternative crops, nutrient management, and weed biology.

8. Presenting data to Young Farmers Groups in the area. The groups are composed of beginning farmers.

9. Cooperating with the Eastern Colorado Range Station by guiding their cropping systems decisions and integrating cropping with livestock production. Presented cropping systems data at their annual winter meeting.

10. Hosting tours composed of foreign visitors, explaining our cropping systems and research systems.

11. Presenting research data at the Great Plains Fertility Conference, the National Wheat Management Conference, and the International Soil Science Society Conference.

THE IMPACT OF USING SWINE WASTE AS A FERTILIZER AMENDMENT ON GROUNDWATER QUALITY

Author(s) Mahdi Al-Kaisi

Problem

The increase in swine facilities in northeast Colorado in recent years increases the concern of the public about the potential groundwater contamination. The major concern is the use of swine effluent on the field as a fertilizer amendment.

The environmental concern with use of the swine waste as fertilizer amendment may impact the groundwater quality, which is the major water source for domestic and agricultural uses. New industry to the area and the lack of any local data on this issue created a lot of speculation and unfounded fears. Therefore, Colorado State University, along with USDA-ARS, developed a proposal to address this issue. The objectives of this study are: 1)Evaluate swine waste impact on water quality and crop production under different application rates. 2) Evaluate the NO3-N leaching under both dry and irrigated conditions. 3) Determine the amount and rate of nitrogen mineralized and released from organic waste under local dry and irrigated conditions. 4) Develop best management practices for using swine waste as a fertilizer amendment. 5) Estimate the economic impact of using animal waste as compared to chemical sources of NO_3-N.

Approach

For Objective 1, four rates of swine effluent will be applied. Similarly, four rates of commercial fertilizers will be applied. These rates will be used under both dry and irrigated conditions. The crop indicator will be corn. Yield will be measured.

For Objective 2, deep soil sampling will be taken at different times of the study. Initial soil samples will be taken, frequent soil sampling during the course of the growing season will be taken, and at the end of the growing season. The soil samples will taken at 6 and 12 inch increments for 10 foot depths.

For Objective 3, a nitrogen mineralization study will be conducted to determine the rate of nitrogen mineralization in situ.

For Objective 4, recommendation for best management practices will developed based on the results of the study.

For Objective 5, an economic analysis will be conducted to evaluate the results of both commercial and swine waste source of nitrogen under both dry and irrigated conditions.

Results

Study will be initiated in the spring of 1995.

Future plans

The main goal of this study is to develop local-research-based data that will help in developing a local best management practices related to the use of swine effluent as a fertilizer amendment.

INTEGRATING CROPPING SYSTEMS WITH LIVESTOCK SYSTEMS

Author(s) D. Schutz[1], T. Stanton[1], and R. Anderson

Problem

The Central Great Plains Resource Management Research Unit is exploring alternative cropping rotations, with the goal to increase cropping intensity and consequently, cropping diversity. The CSU Eastern Colorado Research Center (ECRC) at Akron (Range Station) is exploring alternative feeds for effect on weight gain and overwintering of livestock. Inclusion of livestock in the overall production system not only increases potential use and market for alternative crops, but also serves as drought insurance (poor grain crops could be turned into forage).

The purpose of this team effort is to implement alternative cropping systems at ECRC for better utilization of crop aftermath and alternative forages while reducing annual cow costs.

Approach

Studies are evaluating the effect of triticale production for forage on economics of annual cow costs. Cattle grazing triticale forage in the spring will be compared to cattle maintained on standing dormant winter native range and supplemented with protein to determine if overwintering costs can be reduced.

We are also evaluating the effect of feeding sunflowers whole or roasted on gestating cow weight change, calf birth weight, and reproductive performance. Sunflower seed fed whole or roasted will be compared to cottonseed meal for effect on cattle production.

A third study is evaluating potential for grazing crop aftermath by comparing weight gain of cattle grazing 1) native range, 2) cornstalks, or 3) sunflower stalks.

Results

Spring grazing of triticales by cattle is financially favorable compared to cattle grazing native range. Triticales begins spring growth earlier than the range, and supplies high protein forage before the range grasses initiate growth.

Sunflower seed as a feed does not compare favorably with cottonseed meal for weight gain of gestating cows, but sunflower meal offers promise for cattle feed.

Due to an extreme drought, (only 7 inches of precipitation), we were unable to establish stands of corn or sunflower for grazing crop aftermath.

Future plans

Research exploring the integration of cropping systems with livestock production has been requested by numerous producers, and this study's long-term objective is to develop integrated production systems for diversified farms.

[1]Schutz and Stanton are in the Department of Animal Sciences at CSU.

EVALUATION OF ALTERNATIVE CROP ROTATIONS TO WINTER WHEAT - FALLOW

Author(s) R.L. Anderson, D.C. Nielsen, R.A. Bowman, and M.F. Vigil

Problem

Producers in the Central Great Plains practice a rotation of winter wheat - fallow. Fallowing degrades soil by increasing loss of organic matter and organic nitrogen while exposing soil to wind and water erosion. Producers can counter this trend in soil degradation by cropping more frequently. Producers in semiarid regions rely on fallow to stabilize their crop production. However, improved weed control methods during non-crop periods have increased precipitation storage efficiency, thus producers have more available soil water for crop growth. Also, new crop varieties are more efficient in converting water into grain, thus the need for fallow may be less than historically perceived.

This study is evaluating crop rotations to increase cropping intensity and subsequently, reduce the amount of fallow.

Approach

A crop rotation study of 23 rotations was initiated in 1990 on a Weld silt loam at the Central Great Plains Research Station. With all rotations, we are minimizing tillage. With some crops (sunflower and safflower), tillage is required to incorporate herbicides. Three tillage systems, conventional-, reduced-, and no-till, are included in the wheat - fallow rotation as a basis for comparison in soil quality changes. Standard agronomic practices for seeding rates, planting dates, varieties, and weed control are being followed.

Results

To compare the biological productivity of each rotation, yields are expressed on an annualized basis, where the fallow investment is included in calculating yields. Therefore, if wheat - fallow produces 40 bu/ac, the annualized yield is 20 bu/ac/yr, as one half of the producer's land is not producing grain (in fallow). The wheat - fallow rotation yields approximately 1200 lbs of grain/ac, while a wheat - corn - proso rotation yields 1800 lbs of grain/ac. Other rotations that are more productive than wheat - fallow are: wheat - millet, wheat - corn - fallow, and wheat - corn - proso - fallow. The more intensive rotations yield 30 to 40% more grain on an annualized basis than wheat - fallow.

Regression equations based on cropping intensity have been developed for this site. Cropping intensity is defined as the % of crop land in production in any one year. For example, wheat - fallow's intensity is 0.5, where one-half of the land is in wheat and one-half is in fallow. Wheat - corn - fallow intensity is 0.67, while wheat - corn - proso is 1.0. Regressing annualized yields on cropping intensity shows that for this site, maximum biological yield potential occurs when 90% of the land is cropped. This intensity level would reduced the amount of fallowing to only 10% of the crop land in any one year.

Future plans

Yield data from the most promising rotations have been shared with Don Nitchie, Colo. St. Univ. Ext. Serv. economist, who is developing enterprise budgets for each rotation, based on average producer costs. Yield data has also been shared with the Great Plains Systems Unit for use in their GPFARM decision-aid model.

CROP HISTORY EFFECT ON WEED POPULATIONS IN SUMMER ANNUAL CROPS

Author(s)

R. L. Anderson

Problem

Cropping patterns are changing in the Central Great Plains from wheat-fallow to more intensive crop rotations. One major contributing factor leading to this change in cropping is the replacement of tillage operations with herbicides for weed control.

However, public environmental concerns with the use of herbicides may limit or even eliminate future herbicide options. Secondly, several crops grown in this region do not have registered and effective herbicides for in-crop weed control. Because of these potential limitations, producers will need to use non-chemical weed control methods, including management practices that minimize weed seed production within the crop. Minimizing weed seed production in one crop may reduce weed populations in future crops, and subsequently reduce the need for herbicides.

The objectives of this study are: 1) determine the effect of cultural practices in winter wheat (variety choice, seeding rate, and N fertilizer placement) on weed populations in proso millet planted the following year; and 2) rank crop (oat for forage, corn, proso millet, and sunflower) response to wheat cultural systems in relation to weed population dynamics.

Approach

For objective 1, treatments will be composed of all possible combinations of 1) winter wheat variety (Lamar vs Tam 107), 2) seeding rate (45 vs 72 kg/ha), and 3) N fertilizer placement (N applied in April of fallow vs N applied in April + banding N with the seed at planting). Lamar is a tall variety, while Tam 107 is a semidwarf. Summer annual weeds, redroot pigweed, kochia, Russian thistle, witchgrass, and green foxtail, will be seeded at 200 seeds/m^2 in designated sites. Weed populations will be monitored in winter wheat and proso millet. Weed seed production will be measured in wheat.

For objective 2, three cultural systems will be compared: 1) Tam 107 at 675,000 seeds/acre planted in 12-inch rows, N at 60 lbs/ac applied in August before planting (Conventional practices); 2) Lamar at 1 million seeds/ac planted in 12-inch rows, N applied in April before planting; and 3) Tam 107 at 1 million seeds/ac planted in 7-inch rows with N split applied: 45 lbs in April + 15 lbs with wheat seed at planting. Oat, corn, proso millet, and sunflower will be planted in 1996. Summer annual weeds, listed above, will be seeded into designated sites. Weed populations and system effect on yields of wheat and the following summer annual crops will be measured.

Results

Study was initiated in the fall of 1994, with data collection beginning in 1995.

Future plans

A major goal is to develop production systems relying on weed management systems that prioritize cultural practices before herbicides for weed control. These systems will be developed for several crops common in this region.

POPULATION THRESHOLDS FOR JOINTED GOATGRASS AND VOLUNTEER RYE IN WINTER WHEAT

Author(s) R. Anderson, D. Lyon[1], G. Wicks[1], S. Miller[1], P. Stahlman[1], and P. Westra1

Problem

Jointed goatgrass and volunteer rye infest winter wheat in the Central Great Plains, resulting in significant yield losses. Extensive herbicide screening research is being conducted in this region to find suitable herbicides for controlling these species in winter wheat. Also, developing a winter wheat cultivar tolerant to herbicides active on grassy weeds is being explored. If this research thrust is successful, economic threshold equations for each species will enable producers to determine if and when to use herbicides.

This study is developing yield loss regression equations based on plant population of jointed goatgrass and volunteer rye in winter wheat, with six sites in the region.

Approach

This study was established in winter wheat, following the conventional practices for the region of each cooperator. At the Akron site, Tam 107 was planted at 45 kg/ha with a hoe-drill in 30 cm row spacing. The planting date was Sep. 18. The soil type was a Rago silt loam. Jointed goatgrass and volunteer rye were broadcast in separate plots at 5, 10, 25, and 50 plants/m^2 and incorporated with the mulch treader before planting wheat. Initial plot size was 3 m by 3 m. During the spring, two 1 m by 1 m subplots were designated for treatment analysis.

Data goals include: 1) weed density counts 6 weeks after planting and before April 1; 2) winter wheat grain yields; 3) weed seed contribution to dockage and weed seed bank population; and 6) individual plant seed production by weed species. Weather data collected will include monthly rainfall during the study and long-term average for each site. Yield loss data will be used to develop regional regression equations for predicting the economic population threshold for each species.

Results

On a per plant basis, volunteer rye is the most damaging weed in winter wheat. For each plant/m^2, grain yields are reduced by 3% with volunteer rye, and 1% with jointed goatgrass. Yield loss equation for jointed goatgrass is $Y = 1 + 1X$, where X equals number of jointed goatgrass plants/m^2 and Y equals % yield loss. With volunteer rye, the equation is $Y = 0 + 3X$. Based on this study and previous research with downy brome, these three species can be ranked with a competitive index: if one plant of downy brome = 1, then jointed goatgrass = 3, and volunteer rye = 9 within an indexing scale. With volunteer rye especially, these data show that even low populations can cause major yield loss, as only 3 volunteer rye plants/m^2 would cause 9% yield loss.

Future plans

This team is planning research to explore the effect of winter wheat density and planting date on jointed goatgrass interference. This team will hold training sessions in 1995 to explain present management strategies to producers.

[1]Lyon & Wicks: Univ. Neb; Miller: Univ. Wyo; Stahlman: KSU; Westra: CSU.

EFFECT OF CROPPING ROTATIONS AND TILLAGE ON EMERGENCE OF JOINTED GOATGRASS AND DOWNY BROME

Author(s)

R.L. Anderson and D.C. Nielsen

Problem

In the Plains region, jointed goatgrass and downy brome are two difficult-to-control weeds infesting winter wheat, and their seed persists in soil for up to five years. Rotations which include summer annual crops are used by producers to minimize interference of jointed goatgrass and downy brome in winter wheat by decreasing the weed seed population in soil. The weed seed population decreases because the seed germinates or decays naturally before the winter wheat is planted. Rotations lengthens the time before the next winter wheat crop, thus allowing more seed loss in soil. However, choice of summer annual crop may affect germination of these winter annual weeds in the fall of the crop season. If a canopy effect occurs, then producers could target their severely-infested sites for germination-enhancing canopies.

The objectives for this study are: 1) evaluate the effect of crop rotations and tillage on the longevity of jointed goatgrass and downy brome seed in the soil; and 2) determine the effect of summer annual crop canopies on fall emergence of jointed goatgrass and downy brome.

Approach

Four crop canopy choices are being evaluated within 3-, 4-, and 5-year rotations. The rotations are wheat - canopy choices- fallow, wheat - corn - canopy choices - fallow, and wheat - corn - oats for forage - canopy choices - fallow. Two tillage systems are being compared: no-till and reduced-till (one sweep plow operation in the fall). Within each plot, 200 seeds jointed goatgrass and downy brome were spread on the soil surface in a designated 1 m^2 in 1990. Tillage occurred after seed spreading.

Seedling emergence is being recorded weekly for each 1 m^2 site for the duration of the study (5 years). Soil samples will be collected after wheat harvest to estimate the remaining weed seed population in the soil. Jointed goatgrass and downy brome are being planted in the canopies during August to October to measure canopy effect on seedling emergence.

Results

Jointed goatgrass persists longer in the soil than downy brome. Jointed goatgrass is still emerging 4 years after entry into the seed bank, while all downy brome seedlings emerged within 2 years of entry into the soil. Fall emergence (between August and October) of winter annual grasses differs among crop canopies, as for every seedling that emerges in proso millet, 4 seedlings emerge in corn and barley. One tillage operation increased seedling emergence 2-fold compared to not tilling.

If jointed goatgrass and downy brome are present in a field, producers should sweep plow once after winter wheat harvest and grow corn in the rotation. Producers should target proso millet or sorghum for fields that are not infested with winter annual grass weeds. With jointed goatgrass, producers may have to grow summer annual crops for 2 or 3 years in a row to ensure adequate seed bank depletion before planting wheat again.

Future plans

Data will be analyzed and published.

CULTURAL MANAGEMENT SYSTEMS FOR WINTER ANNUAL GRASS CONTROL IN WINTER WHEAT

Author(s) R.L. Anderson

Problem

Herbicides options for within-crop control of winter annual grasses are presently limited, expensive, and ineffective. However, cultural practices can minimize interference and seed production of weeds in crops. By limiting seed production, producers will minimize weed populations in future crops. Cultural practices that affect weed growth include tall cultivars, narrow row spacing, increased seeding rate, and N fertilizer placement.

Research exploring cultural practice effect on weeds has focused on only 1 or 2 practices. This study compares combinations of cultural practices for effect on seed production of winter annual grasses in winter wheat.

Approach

Eight management systems were compared, composed of all possible combinations of 1) winter wheat variety (Lamar vs Tam 107), 2) seeding rate (45 vs 72 kg/ha), and 3) N fertilizer placement (N applied in April of fallow vs N applied in April + banding N with the seed at planting). Within each plot, downy brome, jointed goatgrass, and winter rye were established 7-10 days after wheat planting by use of peat pellets. A conventional system currently used by producers in this region, a semi-dwarf cultivar (Tam 107) planted at 45 kg/ha, was included for comparison.

Winter wheat yield were determined from the weed-infested and a weed-free site for each plot at harvest. Yield components of wheat also were determined for both sites. Tillers/m^2 within each designated site were recorded, 20 spikes randomly selected, and seeds/culm and seed weight determined. Downy brome, jointed goatgrass, and winter rye seed production was measured on a per plant basis for each plot.

Results

Producers can reduce seed production of winter annual grasses at least 40% by combining a tall wheat variety with a seeding rate of 72 kg/ha and applying N fertilizer in April of the fallow season. Banding N with winter wheat seed at planting did not favor winter wheat over weeds, but surprisingly, in some systems with Tam 107, banding N increased weed seed production. Apparently, weed roots reached the N band early in their development, increasing their competitiveness with winter wheat.

Producers will suffer a yield loss growing tall varieties in place of semidwarf varieties, as Lamar yielded 10 - 20% less than Tam 107 in all systems. Reduced weed populations in future crops may compensate for this yield loss.

Future plans

An integrated management system for jointed goatgrass, downy brome, and volunteer rye is being developed, involving rotations, mowing, cultural practices at planting time, and control options within the crop.

WILD BUCKWHEAT ECOLOGY AND INTERFERENCE IN WINTER WHEAT

Author(s)

R.L. Anderson

Problem

Wild buckwheat is a prevalent weed in the Central Great Plains, and causes significant yield losses in wheat. Herbicide options exist for wild buckwheat, but environmental concerns have stimulated a more balanced approach to weed control, where cultural practices are incorporated with herbicide options into management systems. Developing effective integrated management systems for specific weed species requires knowledge about ecological characteristics such as time of seedling emergence, rate of seedling development, and peak growth periods.

This study is characterizing wild buckwheat's emergence pattern, growth and development as affected by time of emergence, and soil water extraction depth, plus developing a yield loss equation based on wild buckwheat populations in winter wheat.

Approach

1. Emergence pattern: 250 seeds of wild buckwheat will be planted 1-2 cm deep in soil in five 1-m^{-2} sites. Seedling emergence will be counted weekly, with seedlings removed after counting. Counts will begin March 1 and continue until wheat harvest. Soil temperature will be recorded with thermocouples and the data logger.

2. Growth and development study: Ten seedlings of wild buckwheat (germinated in peat pellets) will be established in winter wheat starting on April 1 and weekly until May 5. Development will be monitored weekly, and biomass and seed production will be measured at winter wheat harvest. Plot size is 2 m by 3 m.

3. Rooting depth study: Tam 107 winter wheat and wild buckwheat will be established in the following treatment sequence: Tam 107 alone, wild buckwheat alone, Tam 107 + wild buckwheat, and a control of no plants. Access tubes will be placed in the center of each plot. Neutron probe readings will be taken weekly, starting on April 1. Plot size is 3 m by 3 m.

4. Yield loss equation based on wild buckwheat populations: Wild buckwheat will be broadcast to the soil surface in September before winter wheat planting to achieve the following populations: 5, 10, 25, 50, 100, and 200 plants/m^{-2}. Tam 107 will be planted at 45 kg/ha. Plots will be split, with a control included for each population. Infested and control subplots will be harvested from each plot. Plot size is 3 m by 7 m.

Results

Study was established in the fall of 1994, with data collection to begin in 1995.

Future plans

This study will be repeated, then published in Weed Science.

WEED MANAGEMENT SYSTEMS FOR SUNFLOWER

Author(s) R.L. Anderson, D.L. Tanaka[1], and D.J. Lyon[1]

Problem

Sunflower is becoming a major crop in the Great Plains. It is classified as a non-compliance crop in the government program, thus, producers can grow sunflower without affecting their wheat base. However, one obstacle to sunflower production is residue level compliance for the government program. The prevalent herbicide used for weed control in sunflower is treflan, which requires incorporation for effective control. This incorporation eliminates surface residue and results in fields failing to meet the 30% cover requirement after planting. A granular formulation of treflan applied in late fall or early spring and incorporated with a sweep plow has been successful in North Dakota. This technique minimizes residue burial and relies on precipitation to aid in incorporating the granules. This study compares sunflower production systems composed of combinations of tillage and herbicides.

Approach

Six systems were compared, 4 systems within a stubble mulch fallow method and 2 systems within no-till fallow. The stubble mulch fallow consisted of sweep plowing as needed in the fall and spring before sunflower planting. The 4 systems in stubble mulch fallow were: 1) liquid treflan (1.0 lb/ac) applied in May and incorporated with a disk; 2) granular treflan (1.0 lb/ac) applied in October, followed by a second application of granular treflan (0.5 lb/ac) in May; 3) granular treflan (1.0 lb/ac) applied in May; and 4) granular sonalan (1.0 lb/ac) applied in May. No-till fallow consisted of command + atrazine (0.5 + 0.5 lb/ac) applied in late July. The 2 systems in no-till fallow were 5) granular treflan (1.0 lb/ac) applied in May and 6) liquid prowl (1.5 lb/ac) applied in May without incorporation. Treflan in systems 2, 3, and 5 and sonalan in system 4 were incorporated with the sweep plow and mulch treaders.

Using the line transect method, residue levels were measured three times during the fallow season and after planting. Visual estimates of % of plot area that was weed-free were made weekly until canopy closure. Sunflower grain yield and 1000-seed weight were recorded at harvest.

Results

All systems maintained residue levels above 50% until seedbed preparation in early June. With system 1, where the disk was used to incorporate liquid treflan before planting, residue cover dropped to approximately 20%. The other systems had residue cover still > 50% at planting. The split-application system (System 2) with two tillage operations achieved the highest weed control. Applying prowl without incorporation (System 6) was the least effective, resulting in reduced grain yields. Producers can achieved acceptable weed control and maintain surface residue levels with reduced-till systems for sunflower production.

Future plans

Research for weed control in sunflower is continuing in the crop history study, which is monitoring the effect of cultural practices in wheat on weed populations in following crops, such as sunflower.

[1]Tanaka: USDA-ARS, Mandan ND; Lyon; Univ. of Nebraska, Scottsbluff.

NEW RECORDED WEED HOST OF THE SUNFLOWER STEM WEEVIL

Author(s) Scott Armstrong

Problem

The sunflower stem weevil SSW (*Cylindrocopturus adsperus*) was very active this year, especially in early planted sunflowers. Sunflowers grown here at the research station suffered as high as 60% lodging. This lodging is an economic disaster for the commercial grower. The adults are small (.20 inches in length), and brown with irregular white markings. Adults emerge from sunflower stalk residue in June to mate and lay eggs. Eggs are deposited at the base of the sunflower stalk. The larvae that develop from these eggs bore into the stalk and feed on the vascular tissue. By August and September, fourth instar larvae make overwintering chambers at the base of the plant where they overwinter.

Approach

While making some observations on the percent lodging of sunflowers by the SSW on the Research Station, I noticed a Russian thistle plant that had some brown lesions near the base on the main stem and axillary branches. Further observation prompted me to split the main stem and branches. Inside the pithy tissue of the Russian thistle were three SSW larvae much the same as if they were in there main host, the cultivated sunflower. This led to surveys of sunflowers on the station and in a commercial field.

Results

I looked for other Russian thistle in the sunflowers on the station to determine if they were "infested". From five Russian thistle plants collected within the sunflowers, 100% were infested with as few as two, to as many as 29 in per plant. A total of 59 SSW were found in the five Russian thistle plants on the station. All were on the lower half of the plant in the main stem or lower axillary branches. I did not find SSW in a stem or branch that had a diameter of less than one fourth of an inch. After more observation I decided to look at kochia since it was present in the sunflowers. After dissecting five kochia plants, three of them were infested. Four was the highest found on a single plant. The kochia did not appear to show symptoms like the Russian thistle. Weeds in sunflowers from a commercial field were also surveyed to compare with those on the station. Five weeds of each specie were dissected for SSW larvae from a field four miles north and two miles east of the station. The Russian thistle produced a total of five SSW. Four of the five kochia were infested, with a total of eight SSW. The infestation in the commercial field was less than the research station. Russian thistle and kochia have not been recorded as alternate hosts of the SSW in the literature. Previous to this investigative study, it was believed that wild or native sunflowers were the only important alternate host of the SSW. The most important point to be realized from these surveys is that Russian thistle and kochia residue (one fourth of an inch diameter or larger) may serve as an overwintering site for the SSW and thus management of weed residue should follow. This would include keeping fields that are to be planted in sunflowers free of kochia and Russian thistle, or at least controlling them before the main stem reaches one fourth of an inch diameter.

Future plans

The best tool to determine when the SSW approaches economically threatening numbers would be a degree-based heat unit model that predicts the emergence of egg laying adults. The first year's data will be taken this spring.

TIMING OF SPRING TREATMENTS FOR RUSSIAN WHEAT APHID CONTROL

Author(s)

Scott Armstrong

Problem

Early in the spring 1994, a wheat field farmed by Randy Malcom in the far southwest corner of Washington County was heavily infested by Russian wheat aphids. This provided the opportunity to further investigate the most critical time for spring application of insecticides to control of Russian wheat aphids.

Approach

A block of 25 test plots (20' x 50') including ten foot alleys were marked off in a randomized block. On 8 April, four plots were treated (Lorsban SG .5 lb AI/ac, 12 gallons of water) every week for five consecutive weeks. One replication (four plots) on the first treatment of 8 April (Feekes 3-4) was kept aphid free by spraying it a total of three times. Another replication (four plots) were just treated once on 8 April. Aphid densities were measured by taking fifty random tillers out of each plot every week, including one sample from each plot the day the plots were marked off. Each tiller was examined for infestation, damage, or both. The treatment/sample dates and growth stages of the 'TAM 107' were: 8 April, Feekes 3-4; 15 April, Feekes 5-6; 21 April, Feekes 6-7; 5 May, Feekes 7-8. Net return per acre was calculated by extrapolating the yield to an acre basis, and multiplying times $ 3.60 a bushel.

Results

These test plots turned out to have some of the most meaningful, less variable data collected in the assessment of economic loss caused by the Russian wheat aphid. Plots kept aphid free yielded significantly higher than others ($187.62 net return per acre), and allows for an economic comparison of the remaining treatment dates. The plots treated from Feekes 3-4, 5-6, and 6-7 (8, 15, and 21 April) did not differ in yield (g/plot), and the net return per acre averaged $140.00. However, when the insecticide application was not applied until Feekes 7-8 (5 May), a significant ($107.32) loss in net return acre occurred. Although aphid numbers/tiller are not shown, further analysis of the data will be conducted to determine how much yield loss occurred for each percent infested tiller.

Future plans

After further data analysis, this project will be submitted for publication in a journal.

RELEASE AND RECOVERY OF IMPORTED PARASITOIDS OF THE RUSSIAN WHEAT APHID IN EASTERN COLORADO

Author(s) N.C. Elliott, J.D. Burd, J.S. Armstrong, C.B. Walker, D.K. Reed, and F.B. Peairs

Problem

Control options for the Russian wheat aphid fall into three categories: 1) cultural (i.e. controlling volunteer wheat) 2) chemical (e.g. using insecticides) 3) biological (i.e. augmentation of natural and imported insects that attack the Russian wheat aphid). Biological control is the most difficult to initiate, but if successfully established can be the most environmentally sound, and over a long period of time highly cost efficient.

Approach

In 1991, the United States Department of Agriculture, Agricultural Research service, Plant Science Research Laboratory coordinated a cooperative program with the United States Department of Agriculture Animal Plant Health Inspection Service, Colorado State Agricultural Experiment Station, and the Colorado Department of Agriculture to release parasitoids and predators of the Russian wheat aphid. These efforts were made after predators and parasites were collected from foreign countries and colonized in quarantine facilities in the United States. There were a total of seven different species released. The overall goal was to release these beneficial organisms so that they may establish themselves in agroecosystems on a permanent basis. All of the release sites were in Colorado.

Results

From the seven species released, two (*Aphelinus asychis* (Walker), and *Aphelinus albipodus* (Hyat and Fatima) were recovered after one year on the U.S.D.A., A.R.S. Central Great Plains Research Station, Akron Colorado. In addition, *Aphelinus asychis* (Walker) was also recovered near Pritchett Colorado. The recovery signifies that these two exotic parasitoids successfully established themselves in dryland agriculture. The establishment of two out of seven exotic species may sound trivial, but in fact is phenomenal, considering that from all the efforts in biological control, less than ten percent of any introduced beneficial organism becomes established.

Future plans

This report has been submitted for publication by the senior author. Surveys for the recovery of additional exotic species will continue.

RECOVERY OF A FRIT FLY *Rhopalopterum carbonarium* (Loew) FROM MILLET STEMS: IS IT A NEW PEST INFESTING MILLET?

Author(s) Scott Armstrong

Problem

The wheat stem maggot *Meromyza americana* (Fitch) has been recorded as an occasional pest of millet. Female wheat stem maggots lay on the stem of millet from about late July to early August. The symptoms of the larvae feeding are termed blasted heads. Blasted heads can be easily identified because the tissue of the stem, just prior to the head is hollowed out from feeding, which causes the head to bend and hang upside down (still attached to the stem). A field of "Sunup" millet five miles east and one mile south of the research station was identified as having up to 40% blasted heads. This was unusually high.

Approach

One hundred random stems of millet, that appeared to have some feeding damage, were collected from the field and reared to adults in screened cages on the research station. The rearing of adults was necessary for a positive identification.

Results

Two different, but closely related adult species emerged in the cages after approximately two weeks. One species was readily identified as the wheat stem maggot, which is recorded as an occasional pest of millet. The other adults could not be identified, and were sent to a fly taxonomist (Dr. Curtis Sabrosky) for identification. Dr. Sabrosky identified the fly as *Rhopalopterum carbonarium* (common name is a frit fly) which is in the same family as the wheat stem maggot. This frit fly has never been recorded as a pest of millet, and was the most prevalent of the two species.

Future plans

More field surveys will be conducted in millet this summer to determine if either one of the closely related flies are an economic threat to millet production.

METHOD DEVELOPMENT FOR EVALUATING AND QUANTIFYING SOIL QUALITY

Author(s) Rudy A. Bowman

Problem

In the semiarid areas of the Great Plains, continued clean-till wheat-fallow cultivation of the native grasslands has resulted in significant losses of soil organic matter (SOM) because of wind erosion and decomposition. This loss of SOM results in a deterioration of soil quality and a reduction in crop productivity because of attendant losses in soil physical, chemical and biological properties such as rooting depth, water storage and soil aggregation. Total pools of organic C in croplands are sometimes inadequate as predictors of trends in soil deterioration because they may lack sensitivity over the short term (1 to 3 years); but over the long term, this may not be the case. A need exists, therefore, to develop methodology to assess soil quality changes and direction of change. The specific objective was to develop easy sensitive methods based on organic matter content and other soil parameters to assess soil quality, and consequently, long-term soil productivity in croplands.

Approach

The intent is to develop a quantitative index, which hopefully, will integrate losses in SOM due to erosion, decomposition, and nutrient uptake, and gains due to fertilization and net residue inputs and organic matter content from previous cropping. Besides measurement of SOM, labile organic C pools, enzyme activity, and other biologically based pools, bulk density (BD) and depth to lime (solum) were also measured. Thus, a Soil Quality Index (SQI) can be assessed based on comparison of top 6 inches of soil between new alternative cropping rotations (acr) and the conventional wheat-fallow or with an adjacent native sod.

Results

Previous experiments based upon some yield component and solubility of a labile carbon pool, or turbidity as a measure of aggregate stability were generally fair to good but no better than the total SOM content. This is because over a range of different sites and analysts, SOM was more reproducible and less dependent upon sample pretreatment and methodology. Thus, the following equation incorporating SOM, BD, and solum depth was selected.

$$SQI = \frac{(SOM)_{acr} * (BD)_{acr} * (\text{Solum depth})_{acr}}{(SOM)_{sod} * (BD)_{sod} * (\text{Solum depth})_{sod}}$$

The BD is included because it accounts for the looseness or compaction of the sample, and the solum or depth to lime because of its relationship to wind erosion. Within our cropping treatments, SQI ranged from 0.25 where erosion was most severe to 0.90 in a continuous cropping plot.

Future plans

The soil quality index will be evaluated on selected treatments within our cropping systems (WF, WCF, WCMF, WSunF, continuous cropping, grass/alfalfa), and our CRP sites. Although carbon analyses are completed, we still need to finish our depth to lime (Solum) determinations. Thus, a stable value over time would be an indication of some kind of equilibrium reached for that particular cropping system.

SOIL ORGANIC MATTER DYNAMICS UNDER ALTERNATE CROPPING AND TILLAGE SYSTEMS

Author(s) R. A. Bowman, M. F. Vigil, R. L. Anderson, and D. C. Nielsen

Problem

Soil organic matter is important to hold the soil together, to easily infiltrate water, to reduce compaction, and to provide nutrients such as N, P, K, S, and micronutrients. However, the conversion of Great Plains grassland to clean-till small grain farmlands since the mid 19th century has resulted in extensive loss of the native SOM because of wind erosion and decomposition. On a global basis,with about 40% more organic carbon residing in the SOM than in the terrestrial plant biomass, it is easy to see how the conversion of grassland to wheat-fallow could create over time a drop in crop production and a significant increase in global CO_2. On the other hand, if we intensify the cropping system over the WF, and minimize soil disturbance through less tillage, and if we manage water, fertilizer, and pests efficiently, we should be able to reverse SOM loss and increase soil productivity. Our objective, therefore, was to evaluate different cropping systems for their efficiency in water and nutrient use, minimal soil erosion, minimal chemical leaching, and organic matter buildup. While profitability will determine farmer selection of systems, basic information is gathered independent of economic analysis.

Approach

The study is located at Akron CO on a Weld silt loam. Three replications of 60 combinations and permutations of cropping and rotation sequences exist (See report by Anderson, Nielsen, Bowman, and Vigil for treatments). Extensive sampling was conducted on all 180 sites for soluble (dichromate oxidation) and total organic carbon, total N (C N analyzer), and color absorbtivity at 550 nm of NaOH/EDTA extracts. Soil samples were collected at 0-5 cm (2 inches), and at 5-15 cm (4 inches) for stratification and for plow layer evaluations especially under the no-till conditions and mixing under conventional-till.

Results

There was a significant increase in organic C (20%) for reduced- and no-till systems over the conventional-till for the 0-5 cm depth. Since the plots were not broken out from native grassland, about 40% of the organic C was already lost compared to native sod. On a 15-cm basis, however, the C increases were not as large since very little C and N differences were found for the 5-15 cm depth. Results for no-till and reduced-till showed about a 10% increase in organic C over conventional-till. No differences were found for N. For the cropping systems, data for the 4-year and continuous cropping treatments showed a slight increase (5%) over the 2-year wheat-fallow treatment.

Future plans

All 180 plots will be resampled at the 0-5 and 5-15 cm depths. On selected rotations (WF, WCF, WCMF, WSunF, M, WM, WCM, G/Alf, sod), we will also sample the 15-30 cm depth to assess SOM changes from the sod. Data will also be collected on pH, infiltration, bulk density, and stable aggregates over 0.84 mm. Since some of the plots are now showing significant NO_3-N levels in the profile, adjustments will be made to credit this N for future plantings.

P DYNAMICS UNDER ALTERNATE CROPPING AND TILLAGE SYSTEMS

Author(s)

R. A. Bowman and A. D. Halvorson

Problem

No-till systems usually conserve more moisture than clean-till systems, especially when weeds have been controlled. The extra available water invariably results in greater yield benefits from N and P fertilizer, with corn requiring more water and fertilizer than wheat because of its higher dry matter production (50 bushel dryland wheat requiring about 75 kg N and about 12 kg P, with 80 bushel dryland corn requiring about 80 kg N and 18 kg P / ha). The role of water and nitrogen is being studied for efficient use. As cropping continues, other nutrients such as P and micronutrients which are seldom replenished, may become deficient. This need becomes even greater in the eroded areas of the Plains where P is chemically fixed by free lime, and where high P applications may also induce Zn and Fe deficiencies. The objectives of the research, therefore, are to evaluate P availability and cycling under WF and alternate cropping systems where more residue is returned to the soil surface, and consequently, more P recycled from within the soil profile. Information is needed for P use efficiency for subsequent crops such as corn and millet or oilcrops or legumes after wheat in a reduced-till rotation.

Approach

In a Weld silt loam, various soil P parameters were measured at the 0-5 and 5-15 cm depths to assess P availability and cycling in selected plots from our alternate cropping and tillage system study (ACR). These parameters included available P pools such as those extracted by bicarbonate and anion-exchange resins, total soil P, and total soil organic P, residual P and phosphatase activity which is a measure of quickly available organic P.

Results

In spite of crop P fertilization, the sod still contained about 20% more total P than the average for the cultivated (ACR) sites. Rotations with oil crops and continuous cropping (CC) had the most P while the conventional-till (CT) plot had the least. This occurs in the former treatments because of more P recycling to the surface, and less sediment removal because of more residue cover. Data for available P show net P from plant use, mineralization from residue and litter, and native labile mineral P. For this pool, the fertilized plots showed an increase over the sod. Again the oil crops and CC showed higher available P than the CT treatment. As expected the grass and alfalfa treatments showed the highest total organic P content. Of interest in the phosphatase activity data is the relatively high activity for the CT treatment. This, to some extent, may account for the fast disappearance of the SOM in the CT. The available P in these intensive systems, coupled with less erosion of sediment P, suggests that P replacement maintenance program may be a strategy worthy of consideration for long-term equilibrium.

Future plans

Soil P data collection will continue on the ACR plots. New studies will be initiated with Vigil to look at P needs in millet and oilcrops.

COMPARISON OF CRP LAND IN VARIOUS STAGES OF REST WITH WHEAT-FALLOW AND ADJACENT GRASSLAND

Author(s)

R. A. Bowman and R. L. Anderson

Problem

Present Center projects relevant to CRP address soil and vegetation changes on small station plots. Hopefully, with other things being equal, these small plots will reflect the changes occurring in the over 30 million acres of highly erodible cropland set aside in grass for at least 10 years as part of the Food Security Act of 1985. A principal question in this billion-dollar experiment is whether the rested cropland will be able to adequately support cropping again, and under what conditions or restraints this should be done. Obviously, if soil conditions are deemed inappropriate, a site could remain in grass. A main objective of this research, then, is to develop a set of criteria based on soil physical, chemical, and biological properties to determine adequacy for release of CRP lands back to cropping. An opportunity exists in Washington County to extend this field laboratory research to actual on-farm analysis of farmers' fields that have been in CRP for various lengths of time, the longest requiring three more years to complete its 10-year cycle. Data collected will reflect the true state of affairs and magnitude of change for these once fragile lands.

Approach

Six farms in Washington County on the Conservation Reserve Program were selected from data obtained through SCS. Two went into the program in 1986, two in 1988, and two in 1990. These farms were selected because they also had conventional wheat-fallow and native grassland sites nearby. Thus, one can simultaneously evaluate and compare changes under all three conditions: the original system (grassland or rangeland), the traditional farming system (winter wheat-fallow), and the CRP (regenerative system).

Soil parameters measured included: organic carbon, TKN, available P, and pH. Soils were sampled at 0-5 and 5-15 cm with a minimum of three field replications with five composites.

Results

Previous data showed increases in SOM for the CRP sites compared to the conventional wheat-fallow. Generally, results for sod were greater than for both CRP and continuous WF. Data from an evaluation of labile organic carbon (that extracted in base after acid pretreatment) showed about 23% increase over WF for both the CRP and sod sites at the 0-5 cm depths. However, on a 0-15 cm depth basis, the increases were less than 10%. Using total P as an indication of wind erosion, we found about 12% increase in total P at the CRP sites compared to the continuous WF sites. Results from the WF sites showed a reduction of about 21% in total P compared to the native sod.

Future plans

Studies on soil SOM and nutrients will continue this year on the 86, 88, and 90 sites. Physical properties such as texture, water infiltration, and soil aggregation will also be measured. We have also initiated studies on converting CRP lands back to a wheat-based cropping system. We will be using no-till and reduced-till systems to preserve the gains attained during the 10-year period of CRP. We will be specifically looking to see which of these cropping systems will maintain the SOM acquired during the CRP rest period, and thus, the long-term productivity of that soil.

WATER USE, YIELD AND AGRONOMIC PRODUCTION OF ALTERNATIVE CROPS UNDER AN IRRIGATION GRADIENT

Author(s) David C. Nielsen

Problem

Increased use of conservation tillage in the central Great Plains has increased precipitation storage efficiency and made more soil moisture available for crop production, thereby providing greater opportunities for more intensive crop production as compared with conventional wheat-fallow. Future successful and profitable agricultural production will likely be improved with increased diversity of production. Adding new crops to the traditional crops grown in this area will increase diversity. There are many unknowns associated with diversifying agricultural production with alternative crops, such as water requirements, water use-yield functions, rooting patterns, and water stress effects on plant growth, development, and yield.

Approach

Crops tested during the 1994 growing season were canola (Westar), crambe (Meyer), lentils (Indianhead), black turtle beans (Midnight), blue speckled tepary beans, Austrian winter peas, Tinga flat peas, dwarf corn (Cargill 1077), sunflower (Triumph 546), and kenaf.

The plot area was under a solid set, gradient irrigation system. Plots were arranged such that there would be 4 replications of 4 levels of irrigation, with the highest irrigation level being weekly replacement of evapotranspirational losses.

Results

All crops showed fairly linear responses in yield to increasing availability of water and evapotranspiration. For comparison purposes, the seed production (lb/a) given 16 inches of evapotranspiration of the various crops were: canola (1750), crambe (2250), sunflower (1500), black turtle bean (2200), blue speckled tepary bean (2100), dwarf corn (3500). Forage production (dry weight) with 16 inches of ET was: Austrian winter pea (6000), Indianhead lentil (???), Tinga flat pea (5000), dwarf corn (7800), kenaf (8000). Dwarf corn and beans extract water from the 0-36" profile; canola, crambe, lentils, and peas extract water from the 0-60" profile; sunflowers and kenaf extract water from the 0-72" profile. Each of these crops may have some potential as alternative crops for central Great Plains cropping systems. Both bean species appear to do well, even with limited available water, but low residue amounts following harvest may have to be dealt with by employing a cover crop. The beans and corn could be used in years when precipitation fails to recharge lower soil depths and a more shallow rooted species is needed. Kenaf and sunflower require soil profiles recharged to much deeper depths. The beans, canola, and crambe respond greater to inputs of water than sunflower, indicative of sunflower's lower potential as an irrigated crop, but higher potential as a stable producer under the variable water conditions of dryland production.

Future plans:

We plan to continue this experiment without significant changes in 1995. Detailed observations of kenaf will be added. If we have sufficient help we will make some of the other measurements regarding leaf area, and residue production and persistence.

DETERMINING BEST ADAPTED CULTIVARS AND OPTIMUM DRYLAND PLANT POPULATIONS FOR ALTERNATIVE CROPS

Author(s) David C. Nielsen

Problem

Increased use of conservation tillage in the central Great Plains has increased precipitation storage efficiency and made more soil moisture available for crop production, thereby providing greater opportunities for more intensive crop production as compared with conventional wheat-fallow. Future successful and profitable agricultural production will likely be improved with increased diversity of production. The objectives of this experiment were to determine best adapted cultivars and optimum plant populations for alternative crop species.

Approach

Potential adapted alternative crops are continuously being identified through contacts with other researchers conducting similar investigations in other areas of the country, and through literature review. Three crambe cultivars, two pea cultivars, two dry bean cultivars and one lentil cultivar were evaluated, each at two seeding rates. The two seeding rates were higher and lower than recommended rates from other sources.

Results

Dry growing season conditions (May and June precipitation 19% of normal) resulted in very low yields of all crops. Belann was slightly higher yielding (470 lb/a) than the other crambe varieties with yields increasing at the higher population. The dry conditions at and following planting of beans resulted in poor germination, very low stands, and delayed development. Blue speckled tepary bean yielded higher (about 970 lb/a) than black turtle bean 906 which yielded higher than black turtle bean Midnight (about 300 lb/a). There was a tendency for the lower populations to yield higher than the higher populations under these very dry conditions. Forage yields were around 1100 lb/a (dry weight) for Austrian winter peas and Indianhead lentils, and around 700 lb/a for Tinga flat pea.

These crops are all planted into no-till wheat stubble to evaluate production potential as it might occur in rotation with winter wheat. In both 1993 and 1994 uniform plant establishment has been difficult under these conditions so that plant populations have been significantly lower than planned. Production of any of the crops tested so far will require careful management of the preceding wheat crop residue to conserve soil moisture and protect the soil surface from wind erosion.

Future plans

The experiment will be conducted similarly next year with the addition of several other dry bean varieties and kenaf.

NON-WATER-STRESSED BASELINES FOR ALTERNATIVE CROPS

Author(s) David C. Nielsen

Problem

Developing knowledge regarding the effects of water stress on plant growth, development, and yield is crucial to evaluating the feasibility of production of various alternative crops for the central Great Plains. Infrared thermometry and the Crop Water Stress Index (CWSI) offer a simple, quick, and proven method of quantifying water stress. But the method requires knowing crop-specific non-water-stressed baselines which define the relationship between vapor pressure deficit and the canopy minus air temperature differential under well-watered conditions. Published non-water-stressed baselines are not available for many alternative crops. The objectives of this study are to determine non-water-stressed baselines for alternative crops.

Approach

Plots of canola, crambe, Indianhead lentil, Austrian winter pea, Tinga flat pea, black turtle bean, blue speckled tepary bean, sunflower, and dwarf corn were established under sprinkler irrigation. Irrigations were applied weekly to replace evapotranspirational losses. Measurements of canopy temperature, air temperature, and vapor pressure deficit were taken at 30-min intervals from approximately 1000 to 1600 MST throughout the growing season. Measurements were made only under clear sky conditions.

Results

All crops showed fairly consistent linear baselines consistent with the 1993 baselines. Baselines were the same regardless of whether determined from diurnal measurements or solely from midday measurements.

Crop	Intercept	Slope	r^2	Crop	Intercept	Slope	r^2
canola	2.15	-2.52	0.83	black turtle bean	1.64	-2.41	0.86
crambe	2.47	-2.30	0.75	Indianhead lentil	?.??	-?.??	?.??
tepary bean	1.33	-1.89	0.76	AW pea	?.??	-?.??	?.??
sunflower	0.69	-2.15	0.69	T flat pea	?.??	-?.??	?.??
dwarf corn	1.83	-1.38	0.52				

(?.?? indicates that data is not collected at the present)

The stable nature of the baselines suggest that infrared thermometry and CWSI will be a good method for quantifying water stress in future research on these alternative crops in dryland cropping systems.

Future plans

The results will be submitted for publication in 1995. Non-water-stressed baselines will be determined for other alternative crops in future years as these crops are identified and evaluated for production potential.

TIMING OF WATER STRESS EFFECTS ON CANOLA PRODUCTION

Author(s) David C. Nielsen

Problem

Canola is an alternative new crop that may have potential for the central Great Plains, but much is unknown relative to the growth and production potential of canola in this area. Unknowns associated with canola are how water stress at various growth stages affects growth, water use, rooting patterns, yield, and yield components. Knowledge regarding the sensitivity of canola to water stress at various growth stages can help to determine if it will be suited for this environment.

Approach

Canola was grown in small plots that were covered by a rainout shelter during precipitation events. Three replications of four water treatments differing in timing of water application but not total amount applied were established. All plots received 9.2" of water over the growing season. Treatment 1 received equal weekly applications of water; Treatment 2 received no water during grain-filling; Treatment 3 received no water during flowering; Treatment 4 received no water during vegetative development. Evapotranspiration was calculated by the water balance method from neutron probe measurements of soil water content. Leaf area index (LAI) measurements were made with the LAI-2000 plant canopy analyzer.

Results

Contrary to 1993 results, there was no effect of timing of water stress on yield or yield components of canola. Yields were anomolously low (277 to 368 lb/a) considering maximum LAI ranged from 3.3 to 5.5. There was no visual evidence of disease or insect damage. We first attributed the low yields to heat stress from the abnormally warm conditions of 1994, but did not see the same yield reduction in neighboring plots of canola grown in a water gradient experiment. We now suspect the low yields may be the result of sulfur deficiency. The reduction in yields from 1993 results were mostly from reduced seeds per pod and pods per plant.

No interpretation regarding the effect of timing of water stress on yield of canola can be made from the unexplained low yields of 1994.

Future plans

This experiment will be run again, but not until 1996 to avoid potential disease and insect problems (dwarf corn will be grown on these plots during 1995). We will test the soil for nutrient deficiencies.

CROP ROTATION AND TILLAGE EFFECTS ON WATER USE, WATER STRESS, AND YIELD OF ALTERNATIVE CROP ROTATIONS FOR THE CENTRAL GREAT PLAINS

Author(s) D.C. Nielsen, A.D. Halvorson, R.L. Anderson, and S.E. Hinkle

Problem

Increased use of conservation tillage practices has made more soil moisture available for crop production in the central Great Plains, thereby providing greater opportunities for more intensive crop production as compared with conventional wheat-fallow. Information is needed regarding water use patterns, rooting depth, water use/yield relationships, precipitation storage and use efficiencies, and water stress effects of crops grown in proposed alternative rotations for the central Great Plains.

Approach

Seven rotations [W-F(CT), W-F(NT), W-C-F(NT), W-SAF-M(RT), W-C-M(RT), SUN-C(RT), FLEX(RT)] are used for intensive measurements of water use and water stress effects on yield. (W:winter wheat, C:corn, F:fallow, SAF:safflower, M:proso millet, SUN:sunflower, FLEX:flexible cropping, CT:conventional till, RT:reduced till, NT:no till). Measurements include soil water content, plant height, leaf area index, grain yield, crop water stress index, residue mass and cover, and precipitation.

Results

Summer precipitation storage efficiency (PSE) is 3 times higher in wheat stubble than corn stubble, but winter PSE is 2 times higher in corn stubble than wheat stubble. Winter PSE is 3.75 time higher than summer PSE. Spring soil water (SSW) is 2" greater for wheat following NT fallow than wheat following millet. There is on average 1.75" more SSW in corn following wheat than corn following sunflower. Greater availability of SSW leads to greater crop water use, lower water stress, and greater grain yield. Regression coefficients for the water use/yield relationships (lb/a = a + b * [in. of water use]) are:

wheat: a = -2637 b = 390.4	corn: a = -5769 b = 608.1
millet: a = -818 b = 236.7	sunflower: a = -843 b = 160.5
safflower: a = -1698 b = 185.2	

The data collected in 1991-1994 show that the measurements of starting soil water, CWSI, leaf area development, seasonal water use, and yield are all correlated, and that it is important to manage crop residues effectively to capture snow and reduce evaporation. It is apparent that the millet-wheat-safflower and corn-sunflower rotations are too water-demanding for this environment.

Future plans

Water use, water stress, yield, rooting depth, height, leaf area, and growth stage measurements will continue to be made for as long as these rotations exist. We expect to prepare the initial publication of this data in the coming year. We still have plans to use the data collected in this study to validate the model EPIC and run long-term (20-year) scenarios of production under various rotations using Akron weather records as a means of assessing the viability and potential of various crop rotations for this area.

WIND VELOCITY, SNOW, AND SOIL WATER MEASUREMENTS IN SUNFLOWER RESIDUES OF VARYING HEIGHT AND DENSITY

Author(s)

David C. Nielsen and Steven E. Hinkle

Problem

More accurate estimates of soil loss by wind will be possible using the new wind erosion model if wind velocity data for sunflower residues are obtained. The ability of sunflower residues of varying height and stalk densities to trap snow needs to be quantified, as well as the resultant changes in over-winter and spring soil water content to assess the production potential of dryland sunflowers grown in crop rotations in this region.

Approach

Plots with dimensions of 150' by 150' were planted to sunflowers in 30" row spacing with population ranging from 10,600 to 26,100 plants/acre. At harvest, stalks were cut to heights ranging from 17" and 29", or laid flat on the soil surface. Wind velocities were measured with cup anemometers at 6.5' above the soil surface and at 3 to 6 heights within the standing stalks. A silhouette factor was calculated as stalk population * height * diameter. Stalk heights, densities, diameters, residue mass and percent cover were measured after harvest. Soil water content was measured after harvest and periodically throughout the winter and spring using neutron scattering and time domain reflectometry techniques. Snow depth was measured following each snowfall and/or period of high wind with potential for drifting.

Results

Data collected so far cover a range of silhouette factor of 0 to nearly 100. The silhouette factor effectively scales all of the wind velocity profiles regardless of height or population or stalk diameter. A simple relationship has been derived to predict wind velocity at any height within standing sunflower residue. Reduced wind speeds in standing sunflower residues can increase snow catch by three times, potentially adding three inches more available water to the soil profile compared with areas where sunflower stalks were not left standing over winter.

Standing sunflower stalks are effective at reducing wind speed at the soil surface, and increasing snow catch, thereby reducing the potential for wind erosion and increasing precipitation storage efficiency. Even though amounts of residue produced by sunflower are low, SCS should give proper credit to the wind reduction potential offered by standing stalks based on measured silhouette factor.

Future plans

An additional 4 areas are currently being measured for within stalk wind profiles, snow catch and overwinter soil water recharge. Above canopy wind profiles will also be measured to determine standard aerodynamic characteristic parameters. All data will be analyzed and submitted for publication in 1995. A new study will begin (with Merle Vigil) in 1995 to assess changes that occur in sunflower residue mass due to various types and frequencies of tillage operations.

DRYLAND PRODUCTION OF RASPBERRIES WITH CROSS-LINKED POLYACRYLAMIDE (CLP) AND WEED/EVAPORATION BARRIERS

Author(s) David C. Nielsen

Problem

An alternative crop that may have potential as a cash crop in the central Great Plains is raspberries. The development and marketing of CLP, which has the ability to absorb and store large quantities of water, make the production of rainfed raspberries a possibility if sufficient water can be harvested from adjacent non-cropped areas and retained in CLP for later use by raspberry plants. Further enhancement of the benefit from natural precipitation can come from the suppression of weeds and evaporation with a polypropylene weed barrier. Various bed construction factors, rates of CLP, types of weed barriers, catchment area to bed area ratios, longevity of weed barriers and CLP, rainfall/yield relationships, costs of production, and revenues from sales of product will need to be investigated.

Approach

Raspberry beds were established in May 1993 on a grassed rangeland area with approximately 3% slope (sloped to the SW). 1993 Progress Report gives bed details. A split plot, randomized complete block design (3 replications) with presence of weed barrier as main plots and 3 levels of CLP as subplots was established. Plant heights were measured several times during the growing season. Raspberries were hand-picked twice each week.

Results

October 1993 precipitation recharged the raspberry bed soil water, and growth started off very well in April 1994. A severe freeze (minimum temperature of 20 F) occurred on 27 April, setting back all of the plants, but having a greater effect on the high CLP treatments which had more leaf area developed. Water and temperature stresses continued throughout the growing season, with May-August precipitation 51% of normal and the fifth hottest summer in the 87-year record. These stresses combined to cause a complete crop failure during 1994. Visual observations of bed soil water content indicated that hydrated CLP continued to exist in the high CLP treatment throughout the summer. Perhaps the raspberry is unable to extract moisture from the CLP. Plant heights decreased with increasing CLP and increased with the presence of weed barrier.

As in 1993, plant growth during 1994 was enhanced by the presence of weed barrier. Weed barrier helps to make efficient use of rain that comes in very small amounts (< 0.25"). Thirty-two percent of May through September precipitation came in amounts less than 0.25". These small rainfalls accounted for 67% of the total number of precipitation events. The CLP treatments decreased plant growth. We expected under these very dry conditions that the water stored in the CLP would have helped produce a berry crop. It is not clear whether the crop failure was due to high temperatures, or inability of raspberry to extract water from the hydrated CLP.

Future plans

We will continue measurements of plant height and leaf area and yield. We may try to monitor soil water with gypsum blocks during 1995.

NITROGEN RESPONSE OF SPRING AND WINTER CANOLA

Author(s) Merle F. Vigil, Ardell Halvorson, and Bill Beard

Problem

Canola is a potential oilseed crop for the Central Great Plains. Much of the basic agronomic knowledge required to make canola a successful option in the Central Great Plains is unknown. Management information such as variety selection, nutrient requirements, heat unit requirements, and planting date have not been established for canola in our region.

Approach

In this study the N response, and yield potential of 9 spring varieties (Westar, Alto, Parkland, Tobin, Global, Cyclone, Excalibur, IMC01, IMC129) and 3 winter varieties (Touchdown, Glacier, Crystal) are being evaluated in a split-block designed field experiment with varieties as main plots and nitrogen (N) rates as subplots (strip-plots). The experiment is established on a Platner silt loam under two different previous crop-management histories. Site one is established in wheat stubble, site two is established in fallow ground.

In August prior to winter canola establishment all plots are top dressed with 0, 40, or 80 lb N as ammonium-nitrate. Winter varieties are planted mid to late August. Spring varieties are planted when surface soil temperatures reach an average temperature of 4°C (39.2°F) (the last week of March). All varieties are planted 1 inch deep, at a seeding rate of 900,000 seeds/acre, using a Tye no-till-disk drill. For weed control treflan is applied (1-1.5 lb a.i.) preplant with a granule applicator attached to a sweep plow with mulch treaders.

Results

In 1992 we measured up to 1500 lbs of grain with the cultivars Alto and Westar in fallow. Oil yields tend to follow grain yields with Alto and Westar as the best performers. On average a yield advantage of about 500-600 lbs of grain was measured in the fallow verses stubble plots. Pre-plant soil water contents were only 0.3 inches greater in the fallow plots so yield differences are attributed to greater weed pressure in the stubble plots as compared with fallow. These data suggest the N requirement is between 6 and 11 lb of N per 100 lb of grain for the varieties Westar and Alto.

In 1993 hail damage precluded an accurate measure of yields. However, small grab-bag samples indicated that canola yields in 1993 were on average 300 lbs less than in 1992.

In 1994 a dry June reduced yields of even our best varieties to only 350 lbs (Alto and Westar and the IMC varieties). We suspect that sulfur deficiency may have also reduced yields in 1994. We have had little success with winter varieties. Winter-hardiness is the major problem. In 1992 we experienced 100% winter kill. In 1993 we observed an average of 75% winter kill.

From this data we anticipate that canola may have some potential in our region. However for canola to work we need at least the average rainfall in May and June (long term average is 3 inches in May and 2.5 inches in June). In 1992 we received 3 inches in May and 3.9 inches in June (ideal for canola). In 1993, only 1 inch in May and 1.7 inches in June reduced yields. In 1994, 0.85 inch in May and 0.24 inches in June reduced yields.

Future plans

We will end this experiment this year. We will continue to evaluate new better adapted varieties as they become available in strip tests. Varieties with a larger harvest index and better heat tolerance are needed for this crop to be successful in our region.

CARBON AND NITROGEN MINERALIZATION FROM CROP RESIDUES, MUNICIPAL SEWAGE SLUDGE AND ANIMAL MANURES

Author(s) Merle .F. Vigil and Rudy Bowman

Problem

The amount of NO_3-N entering groundwater supplies is a national concern. The NO_3-N entering ground water comes from N mineralized from native soil organic matter, organic amendments of manure and municipal sewage sludge, crop residues, and from fertilizer applied in excess of the amount required for sustainable crop yields. The excess NO_3-N (particularly the mineralized NO_3-N) is not always in synchronization with maximum crop uptake and is therefore potentially leachable. Most laboratories recommending N fertilizer either ignore or simply guess at the amount of N mineralized from organic sources. The problem lies in the complexity of N turnover which is affected by variable soil, and organic amendment characteristics, and variable soil environment from year to year.

Approach

The objectives of these experiments are to determine the amounts and rates of decomposition of organic amendments: manures, crop residues, and sewage sludges in farm soils, and to quantify how much value they may have as fertilizer and soil quality amendments for crop production. Simultaneously we are evaluating computer models for their ability to predict how these amendments will impact soil nutrient availability and crop uptake.

The current system of studies is evaluating the effects of: soil temperature, amendment placement and crop-residue-fiber on the rate and amount of N release (N mineralization) in soils amended. We have shown in earlier work that crop residues can have the same amount of N in them but one will decompose faster. We know this is related to the amount of fiber in the residue. That is crop residues with a lot of fiber will decompose more slowly then those with less. We are conducting laboratory incubations to determine if fiber content combined with N content can be used to predict the rate of release of C and N in soils amended with these amendments.

Results

We have developed a temperature function which is useful for predicting the rate of N mineralization in soils between the temperatures of 5 and 35°C (41 and 95°F). Also our preliminary work suggests that a crop residues N content provides a rough estimate of the amount of fiber in the residue. This is important because crop residue N contents can be measured easily, whereas fiber measurements are difficult.

We estimate from our lab studies that dry-granulated sewage sludge (5.3% N) applied at rates of 1.5 ton and 9 ton per acre will release 30 and 205 lbs of N in a given season under irrigated conditions (about 25% of the total N applied). Under dryland conditions we may only see 15 and 100 lbs of N released for 1,5 and 9 tons of dry sludge. Less sludge N mineralization is expected on dryland because drier soils are less biologically active.

Future plans

Parts of his research will be finished in the next 8 months and will probably be discontinued to allow more time for soil fertility studies with millet (Hershy) and other rotation crops. Other studies (sludge and manure studies) are only in the beginning phases and will be continued.

WHEAT RESIDUE DECOMPOSITION AS EFFECTED BY HERBICIDE AND UAN APPLICATION UNDER FIELD CONDITIONS

Author(s) Merle F. Vigil, R.L. Anderson and R.A. Bowman

Problem

The amount and type of crop residues left on the soil surface after harvest affects soil erosion. For farmers to be in conservation compliance (1985-1990 farm bill) they must have, in accordance with their conservation plan, a specified amount of crop residue cover at planting time. Unfortunately, crop residues decompose after harvest and become less resilient and durable during the non-cropped part of the season. These partially decomposed crop residues can then be wind blown from a field and lost in the same manner as soil. Minimal quantitative information exists on the durability and resiliency of standing crop residues as affected by the applications of herbicide and N fertilizer. The objectives of this research are: 1) To quantify how the durability and resiliency of standing crop residues are affected by applications of N fertilizer, and herbicides under field conditions. 2)To make this information available to farmers, SCS, and to the cooperative extension service through field days, newsletters, popular news articles, fliers.

Approach

Just after wheat harvest (August of 1993) 45 by 16 foot field plots were established with the following treatments where all rates are active ingredient/acre: 1) 0.5 lb Command + 0.5 lb Atrazine applied mid-August. 2) 0.5 lb Glyphosate + 0.25 lb Dicamba (Banvel) applications as needed. 3) 0.5 lb Paraquat + 1.0 lb Atrazine applied mid-August. 4) 0.5 lb Paraquat + 0.25 lb 2,4 D as needed. 5) no treatment, hand weeded (plastic spread over top of hand weeded area). 0.5 lb Command + 0.5 lb Atrazine. 6) tillage, no herbicide 2-3 times as needed (sweep plow with mulch treaders). Superimposed onto these treatments are three N regimes: no N applied, 30 lb N as UAN, and 60 lb N as UAN. All plots are replicated 3 times and arranged in a randomized complete block design. The following measurements are being taken. 1) Photo-documentation of plots was done after plots were established, after herbicide application, and then periodically as needed to document differences or lack of differences due to treatments. 2) The number of standing wheat stems is counted in select areas of each plot once a month during the no-snow months (depending on snow depth). Measurements will continue until planting of the next wheat crop.

Findings

The study has been established since August of 1993. No increase in standing stem loss due to herbicide or N has been measured as of January 5, 1995. Initially a color change could be observed after herbicides and N solutions were applied. However, with time the color differences faded. We have lost about 50-60% of the standing stems originally counted in August of 1993. The loss in standing stems is primarily driven by the number of days with optimal heat and moisture for microbial activity. Herbicide treatments do not appear to be important. We did measure greater standing stem loss at the 60 lb N rate as compared to the 0 or 30 lb N rate (the differences were not statistically significant). This lack of statistical significance may be related to the fact that the summer of 1994 was the driest summer on record at the station.

Future plans

The experiment will be continued with the original plots and a new set of plots in 1995. We will evaluate as the experiment progresses if further study is needed.

WINTER WHEAT AND LEGUMES IN A GREEN-FALLOW CROPPING SYSTEM

Author(s) Merle F. Vigil, Dave Nielsen, and Rudy Bowman

Problem

A system where legumes are planted early in the fallow period (green-fallow) in a winter wheat-fallow rotation is being evaluated. This cropping system has the potential of becoming independent of N fertilizer inputs. The system has potential especially if the legume can be used as a forage for sheep or cattle. However, we are concerned with how much stored soil water will be used by the legume during the fallow period. Whereas the N and forage benefits of the legume may have merit, legume use of stored soil water may reduce wheat yields. No evaluation has been conducted to specifically evaluate the water use required per unit of N fixed of spring and winter legumes in the Central Great Plains. Nor has there been any study in our region specifically designed to evaluate the amount and rate of legume residue N mineralization under field conditions. Most importantly no study has been conducted in our region to evaluate legume cover crop water use effects on subsequent winter wheat yields.

Approach

Three randomized strip-plot field experiments with four replications were established in March of 1994 at Akron, Sterling and Stratton. Main plots consist of Austrian winter peas, spring field pea (Trapper variety), or Indianhead lentils, and a no legume fallow plot fertilized at four N rates 0, 30, 60, and 90 lb N/ac. At Sterling and Stratton only Trapper is being evaluated. All legumes are planted near the end of March. The four sub strip-plots consist of four legume growth termination dates spaced two weeks apart beginning in mid May. Legumes are terminated using sweeps or with a contact herbicide. Soil water contents are measured (neutron probe & TDR) at legume planting in March and at each growth termination event to determine water used. Residue litter bags are used to determine decomposition. Total above-ground-plant N is determined and total legume and weed biomass is determined at each termination date. Inorganic N is monitored at each termination date and at select intervals thereafter. This last fall, wheat was planted using standard BMP's for a wheat-fallow rotation on each legume plot.

Results

We measured 1540 lbs of above-ground-dry matter on June 13, 1994 in our Austrian winter peas (planted April 1). This dry matter contained 57 lbs of N and was produced on 4 inches of water. An additional inch of water produced only 200 more lbs of dry matter with no significant change in total above-ground-plant N. The other legumes produced less dry matter but used as much water. Wheat yields will be measured in July of 1995.

Future plans

We would like to continue this study for a minimum of 8 years. We believe at least four complete cycles of the system will be needed to make a fair evaluation. A second set of plots are being established so that wheat yields and legumes can be evaluated each year.

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GREAT PLAINS SYSTEMS RESEARCH UNIT

Lajput R. Ahuja, Research Leader
Federal Building
301 S. Howes, Room 249
P.O. Box E
Fort Collins, CO 80522
TEL: (970) 490-8300
FAX: (970) 490-8310

FTS2000: a03rlgpsr@attmail.com
INTERNET: ahuja@gpsrv1.gpsr.colostate.edu

MISSION STATEMENT

Provide leadership in synthesis, quantification, evaluation, and enhancement of knowledge to support the development of sustainable and adaptive agricultural production systems that are biologically efficient, environmentally sound, and economically feasible.

TECHNOLOGY TRANSFER - 1994

Great Plains Systems Research

1. Significant program was made toward developing the Decision Support System GPFARM. Discussions with the Unit Users Focus Group helped improve the design. A Users Survey will be mailed out soon. A poster paper and a computer demonstration were presented at the ASA meetings.

2. Participated in national ARS/NRCS effort in transfer of NLEAP technology (along with 4 other ARS water quality models) which consisted of video, workbook, and interactive training of regional personnel and the training of the national and regional NLEAP model support teams. A 1 day INTO TO NLEAP workshop was presented to 13 individuals from private industry (11), state university, and ARS at a request from the Potash and Phosphate Institute in conjunction with the North Central Extension-Industry Soil Fertility Conference. Results of NLEAP/GIS nitrate leaching studies in eastern Colorado were presented to some 80+ participants on the first annual S. Platte Agr. tour near Greeley, CO.

3. We have been working actively with MSEA projects in the Midwest on evaluating the RZWQM - Root Zone Water Quality Model against their experimental data. The RZWQM will be used for integration and transfer of new knowledge and technology over the entire region.

4. Working with the Colorado state SCS Agronomist in using our SHOOTGRO model to simulate biomass production of winter wheat by late fall with a 90% probability in different parts of Colorado. This for their RCA compliance program. Historical weather data from a number of locations were collected, the input parameter files created, the simulations completed, and analysis finished and transfered to SCS. Discussions have been initiated to incorporate the work into the SCS RUSLE software.

5. SPUR2 is being used by the country studies team (EPA, DOE, and others) for climate change research on rangelands. Four countries are currently using the model. Plan a cooperative experimental study at Akron on this subject.

6. Two of our scientists presented invited lectures on "scaling spatial variation to assess groundwater quality in the South Platte Basin."

7. GPSR scientists presented eight papers at professional meetings, and published more than 25 papers.

DEVELOPMENT OF A DECISION SUPPORT SYSTEM FOR FARMERS AND RANCHERS IN THE GREAT PLAINS

Author(s)

L. Ahuja, P.N.S. Bartling, D. Edmunds, J. Ascough II, M. Shaffer, J. Hanson, G. McMaster, L. Wiles, and D. Woodson

Problem

Maintenance of sustainable agriculture in the Great Plains is a complex problem requiring consideration of a range of interrelated factors, processes, and institutions. Across the Plains, agriculture is limited by the supplies of water and nitrogen that are available from the natural system. Supplementing these scarce resources to enhance production without damaging the environment is a major challenge. Past management practices and Federal programs have created special environmental, managerial, economic, and political needs that must be addressed. In the immediate future, the ability to quickly modify farm and ranch management practices to take advantage of the changing global economy; new cropping, pest management, and tillage systems; and future legislation while protecting soil, air, and groundwater resources, will determine whether an agricultural enterprise system survives or perishes.

Approach

The Great Plains Framework for Agricultural Resource Management (GPFARM) whole-farm level computer-based decision support system is being developed to analyze and develop strategic 1-10+ year management plans. GPFARM will provide an operational framework for farm/ranch decision support across the Great Plains including site-specific management, economic, climate, and soils information from which alternative agricultural strategies can be developed and tested. Management of water and nutrients will be stressed along with strong emphasis placed on profitability and simultaneous protection of the environment with respect to soil erosion, nitrate leaching and pesticide transport. GPFARM will include a GIS and precision farming linkage, multicriteria decision theory and risk analysis components, an object-oriented framework integrating the interface, science modules, and databases, and object-oriented simulation of soil-plant-animal processes.

Results

Design work has proceeded on the user interface portion of GPFARM Phase 1, with demonstration of the interface and system at a national meeting. Progress was made towards developing the decision framework theory, science modules, databases, and an economic module. A user survey was developed to complete the GPFARM requirements analysis process.

Future plans

Interface screen design will be modified and enhanced based upon development experience gained and evaluation results from intended customers. Development of the databases and science modules will continue. The GPFARM team is improving skills in object-oriented design techniques for merging of the science modules, databases, and interface into an integrated system framework. The customer requirements survey will be analyzed and information gained will be used to improve GPFARM. A project management approach that includes a detailed task list, work breakdown structure, resource analysis, and quality control measures has been implemented and will evolve into a inclusive project management structure.

SIMULATING PESTICIDE FATE IN SOILS AND RUNOFF

Author(s) L.R. Ahuja and Q. Ma

Problem

Models are being used to describe and study the fate of pesticides in soil, which have the potential to adversely impact the quality of our environment. Recently, several studies have shown that the commonly used instantaneous sorption models fail to describe adsorbed chemical leaching through porous media. Yet, there are few reports on the simultaneous simulation of adsorbed chemical leaching and runoff behavior by the alternate two-site combined equilibrium/ kinetic sorption (bicontinuum sorption) model.

Approach

We compared simulation results from both sorption models using the ARS RZWQM model for bromide, atrazine and fenamiphos leaching and atrazine runoff from packed air-dry soil boxes under rainfall. In the experiment, atrazine and bromide (as KBr) were applied to the soil surface, and fenamiphos was incorporated into the top 7 cm. Rainfall (10 cm in 2 hours) was simulated 24 hours later. The soil was a Tifton loamy sand series. Model parameters were obtained from the literature or estimated by calibration to the measured atrazine and fenamiphos breakthrough curves (BTCs) and runoff chemograph from one experiment.

Results

Results showed that fast infiltration into the dry soil quickly moved pesticide into deeper soil layers, leaving little time for pesticides to attain equilibrium with the soil. This dynamic characteristic of the system makes the instantaneous equilibrium sorption model invalid. Thus, the bicontinuum sorption model better described the system, simulating the measured runoff and leaching amounts, the BTCs and the runoff chemographs well. With the same parameters, the instantaneous equilibrium sorption model underestimated pesticide leaching and overestimated pesticide runoff. Since most field soil systems are highly dynamic, it is expected that the bicontinuum sorption model will better predict pesticide behavior in the field. The kinetics of pesticides is especially important for predicting leaching of the chemicals from the top soil and their subsequent transfer to runoff water.

Future plans

Sensitivity analysis showed that the BTCs of atrazine and fenamiphos were sensitive to f, the fraction of sorption sites in equilibrium, and that atrazine runoff was sensitive to b, the extent of mixing between soil and raindrops. Since the factors upon which f and b depend could have varied between experiments, further research is needed to quantify how f and b are affected by these factors.

MODELING THE RAINFALL RUNOFF-PROCESS ON RANGELANDS INCORPORATING SMALL-SCALE SPATIAL VARIABILITY

Author(s) L.R. Ahuja, J.D. Hanson, F.R. Fiedler, G. Frasier[1], J.D. Salas[2]

Problem

Optimization of plant and animal production from rangelands is dependent on management of the limited water supply in these areas. Grazing intensity has been shown to affect the rainfall runoff process. In general, higher grazing intensities lead to decreased infiltration, which in turn decreases plant and subsequent animal production. This study characterizes the effect of different grazing intensities on small-scale spatial variability of factors that control the rainfall-runoff process. Physical experiments and computer modeling will be used to complete this study.

Approach

Four experimental plots, 10'x 30', were established on the Central Plains Experimental Range. Selected areas represented season-long light and heavy grazing intensities. A rotating-boom rainfall simulator was used to generate rainfall. High-accuracy flumes were used to measure the runoff over time. Microtopography of the plots was measured using a laser profilometer. These data also provided vegetation and bare-spot distribution information. Tension infiltrometers were used to measure hydraulic conductivities of at least ten bare spots and ten vegetated spots under each grazing intensity. Soil cores were collected outside the plots to determine soil bulk density, organic matter, texture, water retention curves, and wetability.

Results

Data are currently being analyzed. Background research has been done to develop a mechanistic model for infiltration and overland flow that explicitly includes the small-scale spatial variability of soil properties and microtopography.

Future plans

A computer model capable of incorporating data collected at a small spatial resolution will be developed and verified using data collected from the experimental rainfall-runoff plots. Simulations will be run to extrapolate to larger scales and specifically testing the effect of grazing intensity on plant and animal production in response to water management.

[1] USDA, ARS, Range Resource Research Unit, Fort Collins, Colorado
[2] Department of Civil Engineering, Colorado State University

RESIDUE ARCHITECTURE IMPACTS ON SOIL HEAT AND EVAPORATION

Author(s) R. Aiken, D. Nielsen[1], G. Flerchinger[2] and L. Ahuja

Problem

Residue architecture (standing height, percentage soil cover, reflectance, etc.) modifies soil warming and water conservation by shading and 'insulating' surface soil layers. Decay of residue, dependant upon temperature and water conditions, results in seasonal changes in residue architecture, with impacts on soil temperature and water status. Evaluation of residue management alternatives is enhanced by accurate quantification of residue effects on soil heat and evaporative processes.

Approach

Soil warming and evaporative processes are quantified in Root Zone Water Quality Model (RZWQM) and Simultaneous Heat and Water (SHAW) modules. Sheltering and shading effects of crop residue and canopy cover on surface temperatures are quantified in PENFLUX, a new RZWQM module. Surface temperatures, predicted by PENFLUX, provide direct linkage of SHAW soil heat and RZWQM evaporation modules for a full range of residue and canopy conditions. Windspeed and temperature sensors quantify conditions within dryland wheat standing residues (CSU Horticulture Farm, GPSR site) and irrigated sunflower standing residues (Central Great Plains Research Station, CGPR site). Components of the soil energy and water balance were quantified at both sites by net radiometers, pyranometers, soil heat flux plates and soil moisture sensors. These data are compared with simulated surface temperatures to determine the predictive accuracy of the linked soil heat and evaporation modules.

Results

Initial field evaluation indicates the predictive accuracy of PENFLUX is within 1°C for surface soil temperature and 10 watt m^{-2} for net radiation above flat wheat residues. Sunflower and vertical wheat residues introduced similar aerodynamic drag factors, though differing in architecture, reducing near-surface wind speeds to 20% of reference speeds (2 m). Reduced turbulent mixing within the vertical residue sub-layer tended to 'insulate' the soil surface from cooler ambient mid-day temperatures. Reflected short-wave radiation was reduced for new residues, attributed to back-scattering among vertical residue elements. Sensitivity analysis indicates iterative solutions for surface temperature or use of Penman-type energy balance equations are required to enhance the information content of predictions given uncertain soil, residue and weather information.

Future plans

Field quantification for wheat and sunflower residues will continue at the GPSR site through August, 1995 and at the CGPR site through May, 1995. Data processing and analysis will support manuscript preparation and submission for peer-review publication. Archived data will also enable field validation of residue effects on energy exchange processes simulated by RZWQM v 3.0, under development at GPSR. Applications to residue decomposition and spatial integration at the field and watershed scale will be developed.

[1]Central Great Plains Research. [2]Northwest Watershed Research Center.

DEVELOPMENT OF THE WATER EROSION PREDICTION PROJECT (WEPP) WATERSHED MODEL

Author(s) James C. Ascough II, M. Nearing, C. Baffaut, S. Livingston, D. Flanagan, and J. Laflen

Problem

The USDA-ARS Water Erosion Prediction Project (WEPP) project contains hillslope, watershed, and grid model versions. The USDA-ARS National Soil Erosion Research Laboratory and the Great Plains System Research Unit are working together to develop the watershed model. The model predicts erosion effects from agricultural management practices and can accommodate spatial and temporal variability in topography, soil properties, and land use conditions within small agricultural watersheds. It consists of three primary components: hillslope; channel; and impoundment; and extends the erosion prediction capability of the hillslope model through estimation of sediment yield from areas where channel processes contribute significantly to soil erosion.

Approach

The watershed overland flow component calculates rainfall excess by a modified Green-Ampt infiltration equation; peak runoff rate by kinematic wave routing or simplified regression equations; interrill erosion as a process of soil detachment by raindrop impact and sediment delivery; and rill erosion as a function of sediment detachment and transport. Detachment, transport, and deposition within grassed waterways or ephemeral gullies is calculated by a steady state solution to the sediment continuity equation. Channel transmission losses are calculated by an analytical solution to the Green-Ampt equation as a function of effective matric potential, depressional storage, and saturated hydraulic conductivity. Peak discharge rate at the watershed outlet is calculated using a modified Rational Method equation using watershed characteristics relating time of concentration, runoff volume, and peak runoff discharge. Flow depth and hydraulic shear stress along the channel are computed by regression equations based on a numerical solution of the steady state spatially varied flow equation. The impoundment component routes runoff and sediment through several types of impoundments including farm ponds, terraces, culverts, filter fences, and check dams. The model is limited to describing erosion and sediment yield processes which occur on channels without headcutting, bank sloughing, and perennial flow.

Results

Significant components that have been developed include hillslope overland flow routing to channels, sediment detachment, transport and deposition; plant growth and residue decomposition; channel infiltration and water balance; daily updating of channel hydrologic and erosion parameters; and impoundment runoff and sediment routing. Progress has been made towards identifying model uncertainties in the hydrologic and erosion components due to errors in model parameters.

Future plans

Inceptive model development efforts are nearing completion. A model validation effort is currently underway to compare measured watershed runoff and sediment yield data with model output. Future model changes will be based on the validation results.

CORN ROOT DISTRIBUTION EFFECTS ON WATER USE AND NITROGEN LEACHING

Author(s)

J. G. Benjamin and L. R. Ahuja

Problem

Water and chemical movement through the soil is of interest to agricultural scientists, farm managers, and others to estimate water availability for crops and to control non-point chemical pollution from agricultural fields. Many models that are used for the prediction of water and chemical movement in the soil either ignore the effects of the plant on water movement or include the plant root system only as a static root distribution. Dymanic, two-dimensional models of the soil and root systems are needed to evaluate many management options such as the placement of fertilizer bands relative to the crop row.

Approach

The objective of this study was to predict root system effects on water extraction by the crop and subsequent effects on nitrate leaching. A 2-dimensional model of the corn (Zea mays L.) root system was developed and linked with a 2-D model of the soil environment. Water and chemical movement in the soil and plant uptake were compared for two hypothetical root systems; a deep, sparse corn root system and a shallow, dense root system. The model was also used to predict the plant uptake of fertilizer nitrogen when applied as a broadcast treatment, a band treatment near the center of the plant row, and a band treatment in the interrow. The volume of water extracted from different positions in the root zone and the nitrogen uptake by the plant were compared for each root system.

Results

Water extraction from the soil varied with the extent of root depth and root density but a large portion of the water needed for transpiration was taken from a shallow depth directly beneath the plant for both root systems. Predicted NO_3^- leaching was less when water extraction by the plant was considered than if no plant was included in the soil system. Changing root distributions had less effect on predicted NO_3^- leaching than on the positional water uptake. Greater fertilizer uptake was predicted when the fertilizer was placed in a band near the row than when broadcast or placed in a band in the interrow.

Future plans

Data that is being collected from an irrigation - fertilizer placement experiment will be used to evaluate and further refine the root growth submodel and the atmospheric interaction submodel. The model will be used to investigate other irrigation - fertilizer management scenarios such as effects of irrigation water timing on plant water stress and the effects of rate of water application from irrigation on total nutrient leaching.

MINIMIZING CHEMICAL LEACHING BY ALTERNATE FURROW IRRIGATION AND FERTILIZER BANDS

Author(s) G. Benjamin, L. R. Ahuja[1], G. Butters[2], L. Porter[3], and H. Duke[4]

Problem

High nitrate levels in groundwater in the Great Plains has been attributed to nitrogen fertilizer applications on cropland. Alternative soil management techniques must be found to allow the use of nitrogen fertilizers on crop land and yet minimize adverse environmental effects.

Approach

An irrigation-nitrogen placement experiment for irrigated corn production was established in 1994 at ARDEC (Agricultural Research, Demonstration, and Education Center) at Ft. Collins, Colorado. Two irrigation water placements, alternate furrow irrigation and every furrow irrigation, and two nitrogen placements, in-furrow and in-row, were tested to determine the plant use of the nitrogen fertilizer and nitrate leaching in the soil. Labeled ^{15}N fertilizer was used to differentiate fertilizer nitrogen from naturally occurring nitrogen in the plant and the soil. Corn physiological development, biomass, total nitrogen uptake, fertilizer nitrogen uptake, corn yield and yield components were measured during the growing season to determine the effects of irrigation water placement on crop growth and the availability of nitrogen to the plant with the various placement options. Soil hydraulic properties, water contents before and after irrigation, and fertilizer nitrogen distribution at the end of the growing season were measured to determine fertilizer leaching.

Results

Preliminary analysis of the first year of the experiment showed that: 1. Little water from irrigation moved below the 1.8-m depth that was considered to be the root zone; 2. Corn biomass and yield were as good with alternate furrow irrigation as with every furrow irrigation; 3. Nitrogen fertilizer uptake was greater for the in-row placement than the in-furrow placement for both irrigation water placements early in the growing season; 4. Total nitrogen uptake and nitrogen fertilizer uptake were less from the alternate furrow irrigation treatment with the nitrogen band placed in the non-irrigated furrow; and 5. Total nitrogen uptake and fertilizer nitrogen uptake were similar among the every-furrow:row placement, every-furrow:furrow placement, and alternate-furrow:row placement by the end of the growing season.

Future plans

Data analysis from the 1994 study including soil nitrogen distributions, soil hydraulic properties, and nitrogen uptake at harvest will be completed. The experiment will be continued in 1995 with plans to include the collection of data to determine soil environmental effects on corn root distributions.

[1]Great Plains Systems Research, [2]Colorado State University, [3]Soil-Plant-Nutrient Research, and [4]Water Management Research

ENHANCEMENT AND REFINEMENT OF NLEAP TO MEET USER NEEDS

Author(s) M.K. Brodahl, M.J. Shaffer, P.N.S. Bartling, and S. Aschmann[1]

PROBLEM

The interest in and use of NLEAP has expanded within State and Federal agencies, within government agencies of other countries, and with private consultants. With this increased interest, necessary program upgrades and enhancements have been identified as well as a need to broaden the application capabilities of the program. In addition, this increased use and interest in the program is making it apparent that distribution, marketing, maintenance, and support requires more resources than the developers alone can provide.

APPROACH

Re-programming will be done in object-oriented design using C++. We will first re-program the simulation portions of NLEAP with the intent that this will address the immediate need of re-using this technology in other software applications being developed by the ARS. As we upgrade the simulation portions, we will enhance the crop handling and crop rotation simulations, add a more flexible soil layering, add simple irrigation scheduling, and add the capabilities for estimating fertilizer recommendations for amount and time of application based on state recommendations. Once this is accomplished, we will re-work components of the current user interface to facilitate movement to a windows interface, expand the program for international use (metric units), expand the program for GIS applications, improve data I/O and file handling, and include program capabilities for facilitating the user configuration of the program.

Results

Throughout the technology transfer of NLEAP we have been accumulating verbal and survey feedback (as well as our own observations of user interaction with the software) on the workability of the software in terms of application and actual "at the computer" use. We are using this information for prioritizing and defining the parts of the program which need upgrading, expanding and re-design. Work has begun on restructuring file handling for more efficient user file storage, more flexible combination of saved data for use in constructing crop rotation scenarios and GIS application. Preliminary work has been done on a system for constructing an NLEAP data set from system components (soils, climate, aquifer, crop & crop management) identified within a regional GIS application and the strategies needed to "meld" these individual components into a reasonable data set for simulation. Re-design of the simulation portion of NLEAP in object-oriented format has begun.

Future plans

We will continue to search for a solution to the problem of software transfer to various customers. Our current intent is to investigate the possibilities of an agreement with private industry to do the marketing, maintenance, program support, and training needed to distribute this product to government agencies and private entities

[1]NRCS, Western National Tech. Center, Portland, OR.

SPATIAL ANALYSIS OF HYDRAULIC AND PEDOGENIC IMPACTS ON CROP PRODUCTIVITY

Author(s) M.K. Brodahl, R.M. Aiken, G.H. Dunn, G.S. McMaster, M.J. Shaffer, and L.R. Ahuja

Problem

Analysis of field experimental treatment effects is confounded by non-random and random distribution of fundamental soil properties, such as horizonation, texture, hydraulic and biochemical characteristics. Pedologists have long recognized that plants can be used as bio-indicators of changes in soil profile attributes. The relative response of an agricultural crop, with genetically similar individuals, can provide a "bio-assay" of spatial changes in micro-site environment. Of particular interest in our study is the integration of the soil environment encountered by the crop's rooting system. Knowledge of spatial effects on dynamic processes can guide experimental design, interpretation of soil and crop response to experimental treatments, and scaling of point-based simulation models for non-uniform soils. Field investigations should 1) provide baseline data on soil textural, hydraulic, and pedogenic properties; 2) test the distribution of these properties for uniformity and homogeneity.

Approach

A dryland spring wheat crop, established in 1993, and a dryland spring barley crop, established in 1994, served as bio-indicators for non-uniform distributions of soil water and nutrient supply. The spatial distribution of soil hydraulic and pedogenic properties, crop stand characteristics, and indices of soil and canopy energy flux were quantified over a 2.8 ha field site using a 30 m or 10 m grid. The joint distribution of these parameters were subjected to factor, cluster and correlation analysis to identify structural features of their distribution.

Results

Spring wheat biomass varied from 2.5 to 8.1 Mg ha^{-1} on a presumably uniform soil within a 2.8 ha field; grain yield ranged from 0.7 to 2.6 Mg ha^{-1}. Spatial analysis of biomass data indicated a biomass production trend over the whole field, identified at a scale exceeding 100m; on removal of this trend, biomass was spatially correlated over a 50 m scale. We attribute this variation in plant productivity to spatial variation in soil quality attributes.

Multivariate procedures, coupled with mapping techniques, extended our ability to detect systematic, yet non-linear trends and structure in soil quality attributes. Soil profiles were grouped into five "clusters" based on attribute patterns of soil profile characteristics (surface horizon organic matter and phosphorous, horizonation, horizon bulk density and soil water content) quantified to 1.5 m depth. Attributes of surface soil layers, to 0.6 m depth, failed to define any of the five soil clusters.

Future plans

Additional soil and plant sample analysis, and data processing are required to complete our spatial analysis of plant canopies as bio-indicators of soil quality attributes. We will test replicability of spatial variation in plant biomass with analysis of 1994 spring barley biomass. These analyses will support manuscript preparation. Archived data will also enable field evaluation of protocols for scaling point-based simulation models to non-uniform field conditions.

ROOT ZONE WATER QUALITY MODEL EVALUATION OF DRYLAND AND IRRIGATED CROP PRODUCTION SYSTEMS IN EASTERN COLORADO

Author(s) H.J. Farahani, L.A. Ahuja, G.W. Buchleiter, G.A. Peterson, L.A. Sherrod

Problem

Considerable resources are needed to experimentally study the impacts of alternate management practices on production and the environment under varying soil and climatic conditions. This limitation necessitates the use of system-wide mathematical models, such as the ARS Root Zone Water Quality Model (RZWQM), to synthesize and enhance our understanding of the natural environment. However, field tests are needed to gauge model usefulness.

Approach

We evaluated the ability of RZWQM to simulate irrigated and dryland/no-till corn production systems in semi-arid eastern Colorado. The particular site selected for the center-pivot irrigated corn evaluation was monitored during the 1970's to determine the effects of various fertilizer and irrigation management practices on the fate of water and nitrogen within and below the root zone. Vacuum extractors, buried below the root zone, were used on farmer-owned corn fields to collect percolating water which was analyzed for nitrate leaching. Two dryland sites which have been under various no-till cropping systems for the past decade were selected for model evaluation. We focused on the corn and fallow phases of the wheat-corn-fallow system in an effort to develop a better understanding of the effectiveness of residue to retard soil evaporation. For this purpose, a newly revised evapotranspiration (ET) model that predicts ET from bare and residue covered soil and crop transpiration was formulated.

Results

Comparison of model output against measured data indicated that seasonal predicted values for crop water use, soil water, seepage of water and nitrate below root zone, nitrogen uptake, and grain yield/biomass production ranged from 1% to 28% of measured values. We feel RZWQM can be used to simulate sprinkler irrigated corn growth and evaluate the effects of alternate management practices on nitrate leaching in potentially vulnerable sandy soils. In the dryland study, RZWQM was found to respond to changes in available water between differing slope positions, soils, and site locations as reflected in predicted yield/biomass, soil water and crop water use. Results suggest that model has the capability of simulating rather extreme conditions encountered in dryland agriculture in eastern Colorado. Most importantly, the newly revised soil-residue-canopy ET model suggests that residue retardation of soil evaporation is minimal in semi-arid eastern Colorado. The fundamental question remaining is "What are the dominant residue-related mechanisms that may contribute to enhanced soil water storage during the fallow season?" Perhaps, an even more fundamental question is "Is enhancement of soil water storage under no-till management a residue-related process, or merely the consequence of not stirring the soil?"

Future plans

For the 1995 year, we plan to further evaluate the model under different management systems, e.g., furrow and level-basin irrigated corn. We will also investigate the two fundamental questions raised above.

ROOT DISTRIBUTION UNDER ALTERNATE FURROW IRRIGATION

Author(s) J.D. Hanson, R. Howard Skinner, and Joe G. Benjamin

Problem

Alternate furrow irrigation of corn, with fertilizer placement in the nonirrigated furrow, provides a potential means of reducing nitrate leaching and groundwater contamination. Several studies have shown that roots tend to proliferate in areas where water and/or nutrients are found in abundance, however, the effects of spatially separating water and nutrients within the soil profile on root distribution have not been investigated. Separating fertilizer from the water supply may reduce N uptake and plant growth since N supply to the root system in high productivity systems relies heavily on mass-flow transport in the soil solution.

Approach

Four combinations of water and N placement will be used including: 1) uniform application of water and N to both sides of the row; 2) restriction of water and N to the furrow on one side of the row; 3) water in one furrow with N placement directly in the row; and 4) water in one furrow with N placement in the nonirrigated furrow. Corn roots and shoot will be sampled four or five times during the growing season, at V6, (possibly V9), V12, R1 and R6 in plots fertilized with ^{15}N-labeled fertilizer. Soil cores for root distribution, root nitrogen concentration, and soil nitrate determinations will be taken in 30 cm increments to a depth of 120 cm from a 3 x 3 sampling grid centered over a single corn plant which will be harvested for shoot biomass and N content. Total plant water use and xylem nitrogen concentration will also be determined.

Results

This is a new project and no data have been collected to date.

Future plans

Data collection will begin in the summer of 1995 and continue in 1996. Besides the information obtained on root distribution under the different treatments, this project will provide data on treatments effects on total N uptake, N circulation and partitioning both between roots and shoots and also between roots growing in fertilized and nonfertilized soil, and on the relative contribution of mass flow and diffusion to N supply to the root surface.

CONTROL OF NITROGEN PARTITIONING IN PERENNIAL GRASSES FROM ECOSYSTEMS WITH LIMITED NUTRIENT SUPPLY

Author(s) Jon D. Hanson and R. Howard Skinner

Problem

Experiments in controlled environments have suggested that more N is supplied in the xylem to shoots than can be used for shoot growth. Excess N is recycled back to the root for utilization in root production. The implication is that N partitioning is controlled by shoot utilization rather than by the root. These experiments are generally conducted, however, under conditions where root:shoot ratios are low and most of the N is partitioned to the shoot. This study will address the question of whether or not N recirculation occurs in range grasses growing in the field under less than ideal conditions where root:shoot ratios are high and where much more of the total N is partitioned to roots.

Approach

Nitrogen recycling will be investigated in blue grama (*Bouteloua gracilis)* growing at the Central Plains Experimental Range (CPER). Plants will be divided into roots, shoots and crowns, and sampled three times during the season: 1) during spring vegetative growth; 2) during reproductive development; and 3) in late summer or early fall. Partitioning to shoots should be greatest during the first and second samplings, and least in the third when reserves are being stored for overwintering. At the beginning of each sampling period, plants of uniform size will be preselected and marked. Harvested plants will be randomly selected from this group, and sequential harvests will be conducted to determine dry matter and N accumulation, plant water use, and xylem N concentration. Total N transport to the shoot will be calculated by multiplying xylem N concentration by cumulative transpiration. N recycling will be determined by comparing N transport in the xylem stream with shoot N content. If recycling is occurring N transport to the shoot will be greater than shoot N content.

Results

This is a new project and no data have been collected to date.

Future plans

These experiments are planned to begin during the 1995 growing season, and will be repeated in 1996.

CARBON AND NITROGEN REMOBILIZATION FOLLOWING DEFOLIATION

Author(s) Jon D. Hanson, R. Howard Skinner, and Jack A. Morgan[1]

Problem

Following defoliation, both photosynthesis and N uptake cease or are greatly reduced for a period of time. Initial shoot regrowth depends on reserve N and C stored in root and crown tissue. We are interested in determining the relative importance of stored C and N in the regrowth process, which specific reserves are remobilized, and how the re-establishment of root:shoot ratio following defoliation can best be modeled.

Approach

A forage legume (alfalfa), a C_3 grass (western wheatgrass), and a C_4 grass (blue grama) will be grown in growth chambers with two atmospheric CO_2 concentrations and two soil N levels to provide a range of C and N storage levels in crowns and roots, as well as a range of external supply conditions for regrowth. Following defoliation, sequential harvests will be made at 0, 3, 6, 10, 14, and 20 d, and plants separated into root, crown and regrowth tissue. Total dry weight and total Kjeldahl nitrogen for each tissue will be determined along with regrowth leaf area. Nitrogen pools will be partitioned into nonsoluble proteins, buffer-soluble proteins, and low molecular weight N compounds (amino acids, etc.). Carbon pools will include structural dry matter, water soluble carbohydrates, and starch. Nitrogen and carbon remobilization and uptake will be determined by changes in the respective pool sizes of each tissue. Results will be compared with several root:shoot partitioning models to determine which best describes the regrowth process.

Results

This is a new study and no data have been collected to date.

Future plans

This growth chamber study will be conducted before the field season begins in 1995, and during the late fall/winter of 1995/96. At some time in the future, plants may be preloaded with ^{15}N before defoliation to more closely follow the fate of remobilized N, especially if it appears stored N might be used for root as well as shoot growth.

[1] USDA, ARS, Range Resource Research Unit, Fort Collins, Colorado

SIMULATING PLANT PRODUCTION USING RZWQM: MIDWESTERN STATES EXPERIMENTAL AREAS (MSEA)

Author(s) J.D. Hanson

Problem

The MSEA project was charged with determining the "best management practices" (BMPs) for various regions of the midwestern United States. To accomplish this goal, the MSEA coordinators chose to use RZWQM. For the project to be considered successful, the RZWQM plant component was required to predict yield of corn within 15% of the values measured at each MSEA site.

Approach

The plant growth component of RZWQM was review to assure the code correctly represented the-state-of-the-art thinking in plant physiology. Modifications were made in the way the model handled nitrogen and the system was buffered to compensate for slight errors made by other components of the RZWQM framework. The model was subsequently calibrated for data from each site. Independent data sets were used to determine the percentage error in yield production. To help the MSEA scientists quickly grasp the output from RZWQM, the harvest index was also added to the standard output. Finally, the complexity of running the RZWQM generic model was overwhelming to the MSEA scientists. Therefore, the generic plant parameters were divided into two class: global parameters which are set by the RZWQM developers for each species being simulated and local parameters that can be adjusted by the user.

Results

Five parameters were defined to be local for purposes of the MSEA project. These include the maximum nitrogen uptake rate (NMAX), the amount of photosynthetic carbon to be respired (RESP), the value used to convert plant biomass into leaf area index (CONVLA), the effect of age on propagule development (AGEP), and the effect of age on seed develop (AGES). The mean and coefficient of variation of these variables was NMAX (5.9, 9.3%), RESP (0.26, 50.8%), CONVLA (11.45, 2.4%), AGEP (0.72, 16.0%), and AGES (0.53, 19.7%). Therefore, most attention must be place on correctly determining the amount of carbon to respire. Close attention must also be paid to the age effect variables. The mean value for NMAX and CONVLA can probably be used for most simulations.

Future plans

RZWQM will be used to investigate the BMPs for each of the MSEA sites. Publications will produced documenting the generic plant growth model and results from the BMP investigations. Modifications to the model will be made as deemed necessary by our users and development team.

SIMULATING WATER AND CHEMICAL IN TILE OUTFLOWS

Author(s) K.E. Johnsen, L.R. Ahuja, P. Singh[1], S.E. Walker[2]

Problem

The problem of contamination of ground and surface water by agricultural chemicals is illustrated by a situation encountered in some areas of the Midwest where fertile crop land has been recovered from fields with a high water table by installing drainage systems. Such saturated soils have an increased risk of polluting the environment due to the transport of chemicals to the near groundwater table, or to surface water at the drain outlet.

Approach

Enhancements to the Root Zone Water Quality Model to simulate high, fluctuating water tables and flow out tile drains have been implemented and have begun to be evaluated against field data from sites in Illinois and Iowa. Since these outflows may be indicators of potential ground and surface water contamination sources, the model may be used to study the effect of management practices on tile outflows and water quality.

Results

RZWQM was used to predict nitrate losses from tile drains monitored in the Little Vermillion watershed in East Central Illinois. A qualitative comparison of daily tile flows shows that the model captures typical flow events well, but did not predict large and small tile outflow peaks. Nitrate mass peaks tended to be overpredicted. The model was then used to look at several management scenarios.

The model is in the process of being evaluated against measured data from Nashua, IA. Water, NO_3-N, and pesticide concentrations in drain flows were monitored for four different tillage systems: chisel plow, moldboard plow, no tillage and ridge tillage, under continuous corn production. After calibrating the model against one year of data, predicted and observed daily tile flow of water, daily NO_3-N and pesticide concentration in tile flow, and total tile flow will be compared. Preliminary results indicate that the model is able to predict the observed total tile flow of water within 10% for all but one ridge till site. Daily tile flows are more difficult to predict, although the general trends of peaks and valleys in the observed data are followed. Nitrate concentrations in tile flow can also be modeled reasonably well.

Future plans

It remains to compare model predictions at alternative tillage sites in Iowa, to continue to study macropore effects on tile drainage and to improve the simulation of chemical transport to tiles. Analysis of the data should offer insight to the effects of tillage and chemical applications on concentrations in tile outflow. We can then gain an understanding of how to best minimize the negative impacts of agrichemicals on water quality without compromising crop production.

[1]Department of Agriculture and Biosystems Engineering, Iowa State University

[2]Agricultural Engineering Department, University of Illinois at Urbana-Champaign

REDUCTION OF AG-CHEMICAL MOVEMENT BY APPLICATION OF ORGANIC WASTES

Author(s) Q. Ma, G.H. Dunn, R.W. Lober and M. Murphy

Problem

The San Luis Valley (SLV) in south-central Colorado is an important agricultural region in the state. Soils in the region range from loamy sands to sandy loams with very low organic matter content and high permeability. Crop production is accomplished with sprinkler irrigation and the source of the water is a confined aquifer beneath the valley. This aquifer provides most of the valleys urban and rural drinking water in addition to irrigation. Recently, well monitoring has found increasing levels of several agricultural chemicals including nitrates and pesticides.

Approach

Surface soil from a field in the SLV was used in a laboratory column experiment to determine if some organic wastes could be applied to soil at reasonable levels to: (1) reduce leaching of ag-chemicals, (2) increase water holding capacity, and (3) reduce nitrogen fertilizer requirements. Three organic waster materials, composted sewage sludge (SLD), composted turkey manure (TKY), and barley straw (BAR), were applied to duplicate columns at a rate designed to increase the organic matter content of the surface 10 cm to three percent (3%). Two columns received soil but no organic wastes and were check treatments (CK). Potassium bromide (KBr) was sprayed on the soil surface of each column at a rate of 100 ppm. Metribuzin, a potato herbicide used in the SLV, was also sprayed on each column at the label equivalent rate. The columns were irrigated every three days for four months. One centimeter of water was applied to each column on each irrigation regardless of previous evaporation or leaching. The columns were attached to a manifold that maintained -10 kPa presssure at the bottom of each column. Leachate was collected daily for chemical analysis, and at the conclusion of the experiment the columns were cut into 1 cm sections for analysis.

Results

The CK and TKY columns had the highest evaporation rates. Barley straw and SLD had similar evaporation rates and were lower than either CK or TKY. Columns with higher evaporation rates should have lower leachate volume, and this was the case. However, after one half (0.5) pore volume of drainage occured the cummulative amount of Br^- measured in the leachate was significantly higher in the CK and TKY treatments than the BAR treatment. Break through curves (BTC) showed the TKY treatment had C/C_0 of 1 at approximately one half pore volume. The CK and SDG treatments had similar BTCs, but never achieved a C/C_0 of 1. The BTC for the BAR treatment showed suppressed Br^- content of the leachate and peaked well beyond one half pore volume indicating the possibility of by-pass flow.

Future plans

A field experiment was conducted at the same time as the column experiment. The soil samples taken during the field study are still being analyzed. CSU researchers have indicated an interest in the experiment and a plan has been developed to repeat the column experiment with some modifications.

DEVELOPING AND EVALUATING SHOOTGRO, A SMALL-GRAIN CEREAL GROWTH AND DEVELOPMENT MODEL

Author(s) Gregory S. McMaster and W. W. Wilhelm[3]

Problem

Development of small grains has been studied extensively in the past, with major advances made in the 1980's. Indeed, much of our general knowledge of grass development is based on concepts derived from work on wheat and barley. Small-grain development has been shown to be influenced by environmental factors such as water, nutrients, temperature, light, and CO_2, and management practices such as crop rotations, tillage, and residue cover management. Appropriately constructed models should provide a system for testing the effectiveness of alternative management strategies as well as environmental factors. Unfortunately, few existing models predict development accurately enough to allow testing of hypotheses about causes for differential development between management practices, and those models that incorporate environmental factors have not incorporated the leading research of the last couple of decades.

Approach

A group of ARS and university scientists has been established to collaborate on developing a simulation model, called SHOOTGRO, that incorporates the latest research and concepts on small-grain development and physiology. A basic premise is that if SHOOTGRO is to simulate responses to management practices, that the effects of the management practices should be on fundamental factors such as temperature, nutrients, water, and light. In turn, the simulated plant processes must be modeled sufficiently to be able to respond to changes in the fundamental factors resulting from management practices.

Results

Model calibration and evaluation for Colorado and South African conditions and soil types was completed for Version 4.0. The rate of leaf appearance is a fundamental process controlling many developmental and growth processes, and 9 equations predicting the rate of leaf appearance were evaluated with the results incorporated into SHOOTGRO.

Future plans

Modifications made resulting in Version 4.0 need to be further evaluated for a variety of climatic conditions and soil types. To increase the applicability to colder climates, work on the role of vernalization and photoperiod needs to be incorporated better. Field experiments are being conducted to develop this relationship. Also, a winter kill submodel needs to be developed. To evaluate management practices, the phenology model needs to use soil temperature at crown depth for growth stages up to jointing rather than air temperature above the canopy. Also, SHOOTGRO needs a better soil submodel if certain soil management practices are to be accurately simulated.

[3]USDA-ARS, Soil and Water Research Unit, 119 Keim Hall, University of Nebreaska, Lincoln, NE 68583

ESTIMATING FALL WINTER WHEAT BIOMASS PRODUCTION TO ASSIST SCS WITH DETERMINING COMPLIANCE FOR FEDERAL PROGRAMS

Author(s) Gregory S. McMaster

Problem

Eastern Colorado is classified as highly erodible land (wind erosion). If wheat producers want to be involved in, and eligible for, federal programs, then they must take actions to reduce the erodibility of their land. One of the main actions possible is to maintain a specified minimal level of residue cover, especially during periods of maximum erodibility. The SCS considers green biomass as contributing to the total residue cover. However, an accurate method is needed to predict (with a high degree of certainty) the amount of green winter wheat biomass that will develop in Colorado by December 1 in any given year. December 1 was chosen as the date after which little significant growth would occur for approximately 90 days. This prediction is needed to assess the effects that winter wheat can have in erosion control systems. A potential problem could exist for the producer by pursuing large fall biomass production and using up resources resulting in lower final grain yields.

Approach

The SHOOTGRO model is being used to estimate the minimum biomass expected 90% of the time on 1 December and final grain yield of winter wheat. The biomass results will be used in the Wind Erosion Equation (WEQ) and the Revised Universal Soil Loss Equation (RUSLE). Three locations in eastern Colorado were identified (Akron, Cheyenne Wells, and Rocky Ford) that had long-term weather records (> 70 years). Different initial conditions (e.g., planting date, planting density, soil water and N availability) were tested at each location for the complete weather record. The minimum biomass simulated on 1 December 90% of the time was noted, relationships with initial conditions developed, and relationships between fall production and final grain yield examined.

Results

Simulations were run for the three sites and the results summarized and given to SCS. The results are being distributed to all Colorado SCS field offices for use in their erosion control programs through a SCS Technical Bulletin. The primary factors affecting fall biomass production were planting date and total water in the soil profile at planting. Secondary factors were sowing rate and water in the seedbed layer, with soil N at planting having no effect. All factors reduced in effect as planting date was delayed. There was no correlation between conditions at planting and final grain yield.

Future plans

A manuscript reporting the results will be completed. Also, SCS has requested the approach be applied to four other sites in Colorado (near Springfield, Hayden, Alamosa, and Cortez) to better handle the different wheat growing regions of Colorado. Initial discussions have explored applying this approach to other states and for incorporation into the SCS RUSLE and WEQ field office programs.

WINTER WHEAT DEVELOPMENT AND GROWTH RESPONSES TO SOIL MANAGEMENT PRACTICES

Author(s) G.S. McMaster, R. Aiken, G. Dunn, and L.R. Ahuja

Problem

Many different soil management practices are available and promoted for various reasons. In particular, there are many reasons to use no- or low-tillage practices that preserve as much residue cover as possible, especially in dryland wheat production systems. Numerous studies of wheat development and growth have been done, but most have been on responses to fundamental factors such as temperature, water, nutrients, light, and CO_2 under more "traditional" agronomic practices (e.g., normal tillage practices). Because wheat can reach final grain yield in many ways, there is very little understanding how wheat will respond to alternative soil management practices, and equally important, why.

Approach

We believe that the most effective manner to understand how soil management practices impact the winter wheat production system is to first understand how the soil management practices alter fundamental factors such as soil temperature, water, and nutrients. The changes in these fundamental factors then can be measured for their effect on wheat physiology and development, and therefore understand better why the observed yield differences occur. To extrapolate to other soils and climates, process-based simulation models can use the relationships quantified in experiments such as this to further quantify the processes and their interactions.

Starting in 1986, a series of experiments has been conducted to examine different management practices. Starting in 1991, different tillage practices (conventional tillage, CT, and no-till, NT) and residue cover levels (no residue, 0R, normal residue, 1R, and twice-normal residue, 2R) have been tested. Soil and air temperatures, soil water, soil nutrient levels, and heat and gas fluxes over time were followed, and subsequent responses in wheat development and growth observed.

Results

A data archiving system to handle our field and laboratory experiments and enhance the accessibility of the data to our modeling efforts in the unit was completed. This also has aided us both in summarizing the data collected in the past and in doing real-time data analysis and quality control of ongoing data collection.

Once again, in 1993-94, spike number was the main yield component related to yield. All growth stages were reached earlier in CT than NT, and delayed with increasingly greater residue levels. For straw and grain weight and # spikes m^{-2}, CT < NT, and 0R < 1R < 2R. Near-surface soil temperatures were little effected in CT, but in NT, the greater the residue the less variation. NT soil temperatures were less variable than CT.

Future plans

This long-term experiment will be continued, and the data will be used in the SHOOTGRO and RZWQM modeling efforts.

WINTER WHEAT YIELD AND YIELD COMPONENT RESPONSES TO CROPPING SYSTEMS

Author(s) Gregory S. McMaster

Problem

For a number of decades, the dominant dryland wheat cropping system has been the wheat-fallow rotation, normally with several cultivation passes prior to planting. An advantage of this cropping system is that it is a rather easy system to manage, whereas a major problem is that it is not very economically viable. Economic problems are largely due to the fact that the land is fallow for about 15 out of 24 months, and yields are not very high (Colorado state average is about 33 bu/ac) for dryland conditions. If the cropping system can be changed so that cropping intensity is increased, then the percent time the land is fallow is decreased, and hopefully, economic returns are enhanced. Another benefit of increased cropping intensity is that green biomass is on the land for a greater percent of the time, thus helping to reduce erosion. This is important for land classified as highly erodible and eligibility for government programs.

Approach

Research has shown that switching to no-till practices conserves soil moisture, which is the limiting factor in Great Plains dryland agriculture. This small increase in soil water may provide opportunities for trying different cropping systems than wheat-fallow, thus increasing cropping intensity. Yet, the success of alternative cropping systems will be largely a function of the climate and soils of the site. Therefore, different sites along a north-south gradient with similar rainfall but increasing potential ET southward have been established. Treatments at each site (Sterling, Stratton, and Walsh) were situated across a catena of different soils. All treatments use no-till practices. The rotations are wheat-fallow, wheat-corn-fallow, and wheat-corn-millet-fallow. My involvement is trying to understand why observed wheat yields occurred. The starting point was to collect data on wheat yield and yield components.

Results

Wheat yields were not reduced by switching to cropping systems with greater cropping intensity. As in other studies for the Great Plains, the main yield component is number of spikes m^{-2}. My current hypothesis is that spike number is primarily controlled by tiller abortion rates, and secondarily by tiller appearance rates. Under cropping systems with greater cropping intensity, winter wheat is able to maintain or increase its grain yield by reducing tiller abortion rates, thereby increasing spike number.

Future plans

Complete the data analysis and publish the findings. If resources can be obtained, measure a few variables such as the rate of leaf appearance and culm density over time. Currently there are no measurements on wheat being taken during the growing season.

REGIONAL ANALYSIS OF CONTROLS ON SOIL CARBON LEVELS

Author(s)

Keith H. Paustian and C. Vernon Cole

Problem

Models are needed to support research and management of cropping systems and to evaluate interactions between agriculture and climate change as they affect greenhouse gas emissions and the global C balance. A new version (4.0) of the Century model has been developed to facilitate simulation of complex cropping systems. To rigorously analyze the effects of management and climate on soil C dynamics, a thorough multi-site validation is needed to assess limitations and uncertainties in applying the model for local and regional applications.

Approach

A modeling database is being assembled from benchmark data (obtained with funding from EPA) from 35 long-term field experiments across the U.S. and Canada. Climate, crop production, soil and management information provide the necessary initialization and validation data for simulations of historical changes in soil C. Model analysis is being conducted on a subset of 17 sites, located in the Great Plains and Corn Belt. We are also simulating management systems under climate change scenarios for increased temperature and/or increased CO_2.

Findings

Information for all the long-term sites have been incorporated into the database. Simulation of historical C dynamics have been completed for 10 sites. Model results are consistent with observed data on soil C from the sites, particularly given the uncertainties in pre-experimental management histories for some of the sites. Climate change scenarios have been simulated for experiments at 7 sites. Increased CO_2 levels enhanced crop production and therefor increased soil C levels relative to the no change scenario. For C_3 crops (e.g. wheat and soybeans), increases in C inputs, due to enhanced CO_2, compensated for increased decomposition due to higher temperatures. Lower CO_2 responses of C_4 crops (e.g. corn, sorghum) were not sufficient to override increased decomposition associated with warming, yielding reduced soil C. Management usually had a greater impact on soil C than did temperature and/or CO_2. Systems with continuous cropping had positive trajectories for soil C, while summer-fallow systems, with conventional tillage, had negative soil C trajectories for all scenarios. No-tillage increased soil C relative to conventional tillage under all scenarios.

Future plans

We will continue baseline (historical period) model analyses for the seven sites which have not yet been modeled and complete the analyses of potential climate change effects for all sites.

MSEA-GPSR SYSTEMS MODELING PROJECT

Author(s)

Root Zone Water Quality Model Development Team: K.W. Rojas, K.E. Johnsen, J. Hanson, M. Shaffer, R. Aiken, H. Farahani, Q. Ma and L.R. Ahuja

Problem

The MSEA modeling group and the USDA-ARS Great Plains Systems Research (GPSR) unit have been working in a close cooperative effort to improve and validate the Root Zone Water Quality Model (RZWQM). The goal of the work is to improve the model so that it can successfully simulate the complex management systems being studied at the MSEA sites. With that accomplished, the model will be used to study the potential impact on water quality of modifying practices in different management systems, over a wide range of soil and climatic conditions.

Approach

Each MSEA location has the responsibility for evaluating and improving a major process within the model. These processes include nitrogen cycling, transformations, and transport in the root zone (Nebraska), pesticide degradation and transport (Iowa), surface runoff and chemical transport (Missouri), infiltration and preferential flow (Minnesota), and plant growth dynamics and parameterization (Ohio).

The RZWQM team devoted this year to working with the five MSEA modeling post-doctorals and PIs in evaluating the model against their experimental data. Since all the required input data were not measured or available, it was decided that the model be calibrated for unknown parameters against experimental data for one year at each MSEA site, and the calibrated model then tested against data for the other 2 to 3 years. A workshop was held at Ft. Collins to demonstrate a step-by-step iterative procedure to follow - calibrating soil water profiles first, then nitrate profiles, and finally plant uptake and yield. The anhydrous ammonia application method and N uptake part of the plant submodel were refined based on initial experience.

Results

In another workshop, all calibration and evaluation results in corn and soybean were reviewed. The results were generally within 10-20% of measurement values. The plant parameters generally varied within a small range. In Colorado, the model calibrated at one location was tested against 5 other locations for dryland corn and one location for irrigated corn. The simulated soil water, plant water use, N uptake, N leaching, evaporation and biomass were within 1 to 28% of the measured values.

Future plans

The model is now being enhanced for longterm comparison of management systems and crop rotations by adding: (1) a simple snowmelt routine; (2) automation of N application timing and amounts; and (3) continuous multiyear run capability. These new enhancements will be tested before MSEA scientists use this model for their systems. Later plans include: (1) freezing and thawing of soil water; (2) improved ET and heat flux from bare, residue-cover, and canopy areas, with an hourly computational option; and (3) overland flow, soil erosion, and chemical transport in runoff.

SIMULATION OF REGIONAL SOIL NITROGEN GAS FLUXES USING NLEAP

Author(s)

M.J. Shaffer, Post Doc (vacant), M.K. Brodahl, R.F. Follett, and G. Hutchinson

Problem

A need exists for an effective and efficient means of simulating emissions of nitrogen gases from soils across broad geographical areas as a function of soil properties, climate, and management inputs. The NLEAP model was designed as a national tool for nitrogen management and nitrate-N leaching and contains an appropriate submodel for total soil nitrogen gas production. NLEAP has already been adopted by SCS as a primary tool for nitrogen management and water quality evaluations.

Approach

This is a simulation modeling project with some field and laboratory work required to fill critical knowledge gaps, provide specific model validation data, and interact with project cooperators. The primary tasks of the project are to (1) extend the NLEAP denitrification submodel and related submodels to provide estimates of emissions of individual soil nitrogen gas pool components (e.g., N_2, N_2O, and NO_x), (2) test and validate the expanded NLEAP model using a range of data sets from across the United States and elsewhere, and (3) demonstrate the utility of using the NLEAP model in conjunction with a Geographical Information System (GIS) to estimate soil emissions of N_2, N_2O, and NO_x gases across broad landscapes and regions. Specific soil properties modeled will include nitrate-N levels, degree of soil aeration, amount of available carbon, pH, sulfide levels, temperature, and reductase levels. NLEAP will be interfaced to operate directly with available GIS computer software such as GRASS and IDRISI. Emphasis will be placed on the identification and simulation of cropping practices that minimize the emissions of N_2O and NO_x gases from soils.

Results

This is a new project that started in fY '93-'94. Review of the existing NLEAP model has identified areas that need expansion to accommodate the greenhouse gases. Recruiting for the post doc position is proceeding with several good candidates identified.

Future plans

The research will produce a modified and extended NLEAP model suitable for use by SCS and others (including international groups) that is capable of simulating emissions of N_2, N_2O, and NO_x gases from soils as a function of soil properties, climate, and management across broad geographical landscapes. Management techniques will be identified that minimize emissions of N_2O and NO_x gases from soils. The refined and extended NLEAP model will provide regional, national, international decision aid capability to resource managers, regulatory personnel, and others responsible for climate change studies. Appropriate journal and popular articles, training courses, and user's guides will be prepared to report and transfer the results.

DEVELOPMENT AND ENHANCEMENT OF SUBMODELS FOR CROP-WEED INTERACTIONS, SURFACE RESIDUE DECOMPOSITION, AND MINERALIZATION OF SOIL ORGANIC MATTER

Author(s) M.J. Shaffer, L.R. Ahuja, G. McMaster, L. Wiles, R. Aiken, M. Brodahl, M. Vigil, P. Westra[1], R. Waskom[2], and J. Radke[3]

Problem

Development of research models such as RZWQM, NTRM-MS, and our 2-d models, as well as work with application models such as NLEAP has identified knowledge gaps that need additional basic research. Crop-weed interactions, surface residue decomposition, and mineralization pools of soil organic matter are topics where additional field data and model development are needed.

Approach

Field plots have been established at CSU's ARDEC, the CSU Horticulture farm, USDA-ARS, Akron, CO, and with farm cooperators. These plots generally have multi-purposes and allow the introduction of studies that address the above problem areas. Specialized studies often can be added to existing projects where basic information on system inputs and outputs is already being collected.

Results

Plot studies have been established to gather additional data on crop-weed interactions involving proso millet invasion of corn. This information is being used to expand NTRM-MS beyond corn-pigweed competition. Mineralization of soil organic matter is being studied locally at ARDEC and in farm fields, and in conjunction with the MSEA regional project involving RZWQM. We are attempting to develop a fast laboratory method that is field correlated to quantify the fast soil organic matter pool. Surface residue decomposition studies are in progress at Akron and are being started at ARDEC and the CSU Hort. farm. We need detailed quantitative information on how surface residues decay as a function of the high spatial and temporal variability of the micro-climate that exists near the soil surface.

Future plans

These field studies will be continued for several years so that sufficient annual data sets can be collected to allow adequate model development and testing. The NTRM-MS model will be expanded to include several crops and associated weed species. A comprehensive surface residue decomposition model will be developed that simulates decay of standing dead, fallen residues, and fallen residues contacting or incorporated into the surface 1 cm of soil. The soil organic matter study will test the feasibility of using the autoclave method (or a related lab. method) to analyze samples for the N zero pool.

[1]CSU Dept. of Plant Path. and Weed Science.

[2]CSU Dept. Soil and Crop Science.

[3]USDA-ARS, National Soil Tilth Lab.

NLEAP TECHNOLOGY TRANSFER AND DEVELOPMENT OF REGIONAL DATABASES

Author(s) M.J. Shaffer, M.K. Brodahl, P.N.S. Bartling, R.F. Follett, J. Marron[1], and S. Aschmann[1]

Problem

Given the current state of the national farm economy and the renewed concerns about groundwater pollution from nitrates and pesticides, there is an urgent need to find ways to optimize on-farm productions for profit and yet minimize adverse environmental impacts. Farm and natural resource managers lack suitable tools which can provide answers now before additional damage is done to the farm economy and the nation's soil and groundwater resources.

Approach

The NLEAP model is available for use now. At a minimum level, the user needs to know how to acquire and input data, initiate the simulation, and access the simulation results. However, effective use of a simulation model requires the user to understand the system being simulated well enough to provide proper data input and to interpret the simulation results.

Results

The NLEAP model is one of 5 water quality models adopted for use by the U.S. Natural Resource Conservation Service (NRCS). A NRCS national model leader (Dr. Stephanie Aschmann, Portland, OR) has been appointed for NLEAP. Details of NLEAP embedded technology were summarized in the form of a training video series that was later viewed by NRCS staffs at the NTC's and other locations as part of NRCS national training for the 5 water quality models. NLEAP was also the subject of a 5 day NRCS training course to help the NRCS NLEAP training staff develop expertise in the application and use of the model. In cooperation with Dr. Aschmann and colleagues, we designed and developed a NRCS NLEAP training program and workbook. The NRCS NLEAP support team used this material in a 3 day NRCS training of western state Personnel. This training will be used as a prototype for further internal training of NRCS personnel.

The NLEAP Soil and Climate databases continued to be developed, tested and published. The west was subdivided into regions with WEST1 having the most complete data available to draw upon for NLEAP. The WEST1 Database includes soils and climate for Arizona, Colorado, Nevada, New Mexico, and Utah. Regression relationships to predict evaporation, especially in winter, were developed for the WEST1 region.

Future plans

NLEAP ARS training courses will continue to be provided on a regular basis each year. This training is attended by students, NRCS personnel, consultants, extension personnel, and research scientists. NLEAP database development will continue for the remainder of the western U.S. and include investigating additional data resources, and approaches to estimating winter evaporation/sublimation.

[1]NRCS, Western National Tech. Center, Portland, OR.

DEVELOPMENT AND TESTING OF A MECHANISTIC MODEL FOR SOIL GAS FLUX AND REACTION

Author(s) M.J. Shaffer, R.L. Lapitan, M. El-Kady[1], L.R. Ahuja, D. Reicosky[2], and A. Mosier

Problem

Gaseous emissions and transport associated with soil involves complex systems with multi-phase components. Changes in the biological, chemical, and physical composition of the soil can have direct effects on the carbon (C) and nitrogen (N) cycling processes, and the surface/sub-surface evolution and phasic (aqueous and gaseous) transport of soil gases (e.g. CO_2, CH_4, and N_2O. The development of a comprehensive soil gas exchange model, integrated with process-based models simulating the dynamics of the biological and chemical soil processes, and water and heat flow, is needed to provide detailed understanding and quantitative assessment of the dynamics of the C and N balance in the soil, and fluxes of greenhouse gases.

Approach

A finite difference model was developed to simulate advective-dispersive and diffusive transport of the dissolved and gaseous forms of CH_4, CO_2, N_2O, and O_2 in the soil. Mass transport of the gas species was primarily defined by the flux of soil water. Movement of water and heat in the soil and profile distributions of soil moisture content and temperature under saturated, partially saturated, and/or unsaturated soil conditions were determined by linking the gas transport routine to a water and heat flow (CHAIN-2D) model. The dynamic concentrations of aqueous CH_4, CO_2, N_2O, and O_2 at different layers in the soil were determined from a direct interaction between the soil gas, heat, and water transport routines with the root growth, soil chemistry, and nutrient cycling submodels. These include microbe-mediated processes sensitive to the spatial and temporal variations in soil moisture, temperature, concentrations of O_2, CO_2, C, and N substrates. A bicarbonate buffering system was included, in addition to Henry's Law, to quantify the equilibrium concentration of CO_2 in the aqueous and gaseous phases, and assess soil pH.

Results

The project has demonstrated the feasibility of linking classical gas transport modeling approaches with soil microbial and solute chemistry submodels and plant and root growth simulations. During 1994, various aspects of the model were refined and tested against observed data. Comparisons of the simulated profiles of soil moisture, temperature, root length density and biomass, and CO_2 concentration indicated good agreement with the measured data taken from a fertilizer field experiment in a shortgrass steppe. Temporal surface efflux simulations of CO_2 were within the range of values measured at the sites. A 1-dimensional version of the gas model was developed for incorporation into the RZWQM.

Future plans

Model validation and testing will be continued with emphasis on the use of existing soil gas data. We will be evaluating the 1- and 2-dimensional models for use in RZWQM, NTRM-2D, and other comprehensive process models we have in progress. Technology developed in this study will be evaluated and downsized for use in the NLEAP gas modeling project. Close collaboration will be maintained with other on-going soil gas research.

[1]CSU Dept. of Civil Engr. [2]USDA-ARS, N.C. Soil Cons. Res. Lab., Morris, MN.

APPLICATION OF THE NLEAP MODEL TO REGIONAL NITRATE LEACHING IN COLORADO

Author(s)

M.J. Shaffer, B.K Wylie, M.D. Hall[1], R.M. Waskom[2], J. Boyd[2], R. Schierer[3], D. DuBois[4], D. Wagner[5], R.F. Follett, and R. Lober

Problem

High levels of nitrate-Nitrogen (NO3-N) in drinking water supplies pose health risks to humans and livestock. NO3-N in and derived from fertilizers and manures applied to croplands can be moved into underlying aquifers. This nonpoint NO3-N pollution is prevalent in areas with alluvial aquifers where aquifers tend to be shallow and soil profiles contain coarse textured soils. Farm management of nitrogen and water needs to be carefully considered on areas vulnerable to NO3-N leaching.

Approach

Mechanistic modeling and Geographic Information System (GIS) technologies have been combined to map simulated NO3-N leaching in an area in northeastern Colorado where irrigated agriculture occurs over the shallow South Platte River alluvial aquifer. The Nitrate Leaching and Economic Analysis Package (NLEAP) was selected as the NO_3-N leaching model. By combining spatial GIS coverages for alluvial aquifers, irrigated agriculture, center pivots, and soil survey maps, combination scenarios for model simulations were identified. Correlations between NLEAP leaching indices and groundwater NO3-N were done based on data from pumping irrigation wells sampled during the growing season.

Results

Long term steady-state simulations were better correlated to groundwater NO3-N concentrations than single year simulations. Mass of NO_3-N leached was more strongly correlated with regional groundwater NO_3-N concentrations than was the leachate NO_3-N concentration. The simulation of manure applications in the proximity of feedlots provided improved correlations between regional NLEAP indices and groundwater NO3-N. The regional application of NLEAP was expanded to include Weld and Morgan counties. Farm field plots were established to test management alternatives that may potentially reduce NO3-N leaching and to further field validate the NLEAP model.

Future plans

A proposal has been prepared for submission that builds upon the work of the current CSRS funded project entitled "Regional Analysis and Management of Nitrate Leaching Hot Spots Using NLEAP" by integrating the use of regional groundwater modeling to determine the impact of rootzone NO_3 leaching on the aquifer. The groundwater modeling will clarify the processes contributing to nitrate hot spot stability and enable long term simulation of the effects of BMP implementation on aquifer water quality. Additionally, N isotopic ratios will be used to help determine the sources of N accreting to the aquifer in hot spots of concern in northeast Colorado.

[1]CSU, Earth Resources Dept. [2]CSU Dept. of Soil and Crop Science. [3]NRCS, Lakewood, CO. [4]North Front Range Water Quality Planning Assoc. [5]CSU Dept. of Chemical and Bioresource Engineering.

SOIL ORGANIC CARBON CHANGES AS AFFECTED BY TIME AND ROTATION INTENSITY ACROSS AN EVAPOTRANSPIRATION GRADIENT

Author(s) L. Sherrod

Problem

The practice of summer fallow within the Wheat-Fallow (WF) cropping system in the Central Great Plains is a costly practice, both environmentally and economically. Research has shown substantial losses of organic carbon (C) during the past 50-70 years of crop production. By implementing no-till management, conservation of soil moisture is increased enough to support more crops over time than traditional WF. More intensive cropping under no-till management causes an accumulation of crop residues on the soil surface.

Approach

Three research sites in eastern Colorado were established in 1985 across an evapotranspiration (ET) gradient. The gradient ranges from 1000 mm in the north to 1900 mm in the south of open pan evaporation. Rainfall along this ET gradient averages 400 mm annually. All siteshad been under production for more than 50 years using traditional tillage practices. These sites feature a catena sequence of summit , backslope, and toeslope soils which run along a sloping gradient and represent average, poor and depositional soil profile conditions, respectively. Cropping systems managed by no-till practices were imposed across these three soil types with two replications present. These systems are Wheat-Fallow (WF), Wheat-Corn-Fallow (WCF), Wheat-Corn-Millet-Fallow (WCMF), opportunity cropping (OPP). Continuous grass (CG) was also included as a comparison of the native prairie. Soils were sampled in 1986 in 3 depth increments of 0-2.5 cm, 2.5-5 cm and 5-10 cm and each year from 1989 to present and C and N were analyzed. This research will study changes in C and N over time as well as the differences between initial and final carbon levels. All five cropping systems will be included in this study and temperal changes C and N will be analyzed.

Findings

The deposition of residues on the soil surface has formed a residue/soil layer. Significant changes were detected within 4 years. Rotations with less fallow time have allocated the most C in the first 0-2.5 cm depth with the CG and OPP cropping systems showing increases in the 0-2.5 cm and 2.5-5 cm depth. Initial results show a linear response of carbon over time.

Future plans

Temporal changes in C and N will be studied for the three factors of cropping system, soil type, and site (i.e. ET). Regression analysis will be done on both C and N data collected over a nine year period. Some of the main questions that will be addressed with this data are:

1. Are all rotations showing a linear response with time to both C and N?
2. With depths summed, are we gaining, maintaining or losing C and N within a given cropping system?

THE WEED MANAGEMENT MODULE OF GPFARM

Author(s) L. J. Wiles and C. M. Dunan

Problem

A computer-based decision support system at the whole-farm level is being developed. This system, called GPFARM, will be capable of analyzing and developing strategic one to ten year management plans based on the predicted productivity of selected management options and environmental and economic risks. Crop rotations are often planned to address problems with weeds, and weed management can be a large component of the production costs and environmental risks of crop production. GPFARM must include a module that predicts the impact of weed management strategies on crop yield and weed population dynamics.

Approach

The first version of the weed management module of GPFARM will be a simple model based on the structure of the databases and simulation model of GWM (General Weed Management Model). GWM was developed by scientists working in the Water Management Research Unit. It is a decision support system for soil-applied and postemergence weed management decisions in row crops during a single season.

Findings

The weed management module of GPFARM is being parameterized based on information in the literature and parameter values of WDCAM/GWM, a decision support system for weed management in irrigated corn production in Colorado. The first version of the weed management module will not model weed population dynamics since there is insufficient information on weed seed production and mortality to support even a simple model of weed population dynamics.

Future plans

The weed management module will be parameterized first for irrigated and dryland corn production and a wheat-fallow rotation. The major constraint for implementing the weed management module is lack of data to parameterize the model. Field experiments to generate this data will be initiated and as soon as appropriate data is available, the weed management module will be expanded to model weed population dynamics.

GREAT PLAINS SYSTEMS RESEARCH UNIT

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RANGELAND RESOURCES RESEARCH UNIT

Gerald E. Schuman, Research Leader
High Plains Grasslands Research Station
8408 Hildreth Road
Cheyenne, WY 82009
TEL: (307) 772-2433
FAX: (307) 637-6124

FTS2000: a031ccheyene@attmail.com
INTERNET: gschuman@lamar.colostate.edu

MISSION STATEMENT

To provide rangeland managers with information and state-of-the-art technology needed to ensure sustainable and productive rangeland ecosystems in the Central Great Plains. To emphasize rangeland enhancement through development and establishment of superior plant materials, greater species diversity, and improved or alternative ecosystem management.

TECHNOLOGY TRANSFER - 1994

Rangeland Resources Research Unit

1. Terry Booth served as member of the Laramie County Conservation District Range Steering Committee.

2. Terry Booth consulted with Richard Dunne of Wind River Seed concerning native species seed processing and research needs associated with native seeds production and processing.

3. Terry Booth serves on the western regional committee on Seed Biology and Technology.

4. Terry Booth consulted with Dan Wofford, Western Polyacrylamide, Inc., on cased-hole punch planter and weed-barrier/polyacrylamide planting system and development of CRADA.

5. Terry Booth served as President Elect of the Wyoming Section, Society for Range Management.

6. Larry Griffith served on the NRRC Event committee to improve communication and knowledge within the Center.

7. Larry Griffith was cited by the Laramie County Fair Board for 5 years of service at the county fair.

8. Larry Griffith was recognized for his outstanding efforts in preparation of the Unit poster presentation.

9. Pam Freeman was awarded 2 Certificates of Appreciation and a spot cash award for special service to the Unit.

10. The Unit staff participated in the 55th Anniversary Field Day of the Central Plains Experimental Range by presenting poster displays. June 17, 1994.

11. Gary Frasier and Mary Ashby gave a tour of CPER on 2 June 1994 to 5 native Americans students on a CSU summer training workshop.

12. Gary Frasier and Dennis Mueller gave a demonstration of the rotating boom rainfall simulator on 9 July 1994 at the dedication/land-transfer ceremonies of the Sheep Creek riparian research site. The ceremonies were attended by approximately 200 ranchers, Federal and State land managers, Federal and State elected representatives, CSU and University of Wyoming staff, and interested public.

13. Gary Frasier, Mary Ashby, and Jeff Thomas gave a tour of CPER on 10 August 1994 to approximately 45 students from Kenya attending various colleges in the United States. The students were on a multiweek tour of various ecosystems in the United States under the direction of the University of Missouri.

14. Gary Frasier presented a paper "Rainfall Simulation to Evaluate Infiltration/Runoff Characteristics of a Shortgrass Prairie" at the Water Research and Management in Semiarid Environments Symposium in Tucson, AZ. on 1-3 November 1994. The symposium was attended by over 100 researchers in the field of watershed research from around the world.

15. Richard Hart delivered lectures to "Principles of Range Management," Geography of Agro-Ecosystems," "Forest and Range Soils," Range Utilization and Grazing Management," and "Nutritional Management of Range & Pasture Herbivores" classes at the University of Wyoming, and to "Range Ecosystem Planning," "Range Watershed Survey," "Primary Production and Decomposition," and "Environmental Conservation" classes at Colorado State University.

16. Richard Hart participated in rancher workshops on grazing and improved pastures, organized by SCS and Conservation Districts, at Pine Bluffs, Wheatland & Douglas, WY. Presented workshop, organized by Extension Service, on STEERISK and SMART models to students and ranchers, Douglas.

17. Richard Hart served on the Western Regional Sustainable Agriculture Research & Education Review Panel (CSRS), San Francisco, CA.

18. Richard Hart attended meeting of Great Plains Ag. Council task force "Grazing Management in Riparian Areas;" was appointed Chair of sub-group to collect information from explorers' and naturalists' journals on pre-settlement condition of western rangelands.

19. Richard Hart visited and consulted on grazing studies of CRP Research and Demonstration Project, Corning, IA.

20. Richard Hart attended annual meetings of the Colorado Chapter, Wildlife Society and Colorado/Wyoming Chapter, American Fisheries Society, Ft. Collins, CO.

21. Richard Hart presented "Grazing rangelands improves soil quality" to the Wyoming Chapter, Wildlife Society, Casper, WY.

22. Richard Hart attended 1994 Agriculture Articulation Conference, Western Illinois University, Macomb, IL, and workshop "Re-Inventing the Natural Resources Conservation Service" (formerly SCS), Ft. Collins, CO.

23. Jack Morgan participated in a Rangelands and Improved Pastures Workshop sponsored by CSIRO and the Australian government for the purpose of developing a state-of-the-science statement of likely impacts of global change on the Australian rangelands, and to define an initial set of projects for the Global Change in Terrestrial Ecosystems Core project.

24. Dan LeCain attended the 1994 Wyoming Association of Conservation Districts Meeting in Riverton, WY, where he met with farmers and ranchers to talk about the Unit's research on how grazing influences soil quality.

25. Jack Morgan met with Colorado State Extension Agents and also with private industry to supply materials and information on the Unit's research program that deals with managing and breeding strategies for grazing dryland alfalfa in improved pastures and in semi-arid rangelands.

26. Jack Morgan serves on the Western regional committee "Improving Stress Resistance of Forages in the Western United States."

27. Gerald E. Schuman presented lectures at mined land reclamation short-course sponsored by the University of Nevada and the University of Wisconsin in Reno, NV, April 11-13, 1994.

28. Unit staff members attended and presented research findings at the Society for Range Management, American Society of Agronomy, Soil Science Society of America and American Society for Surface Mining and Reclamation national scientific meetings.

29. Gerald Schuman participated as a team member that presented a one-week short-course on land reclamation to industry and public officials in Estonia, May 28-June 6, 1994

30. Gerald E. Schuman and Larry Griffith co-hosted a tour of the High Plains Grasslands Research Station plant materials for Wyoming, Montana, and Colorado SCS staff, June 22, 1994.

31. Gerald E. Schuman participated in the Applied Biology and Chemistry Course for Science Teachers. He lectured on soil chemical and biological process, Laramie County College, Cheyenne, WY, June 27, 1994.

32. Gerald E. Schuman served as a member of Western regional committee "Management of Drastically Disturbed and Altered Lands," Anchorage, AK, July 25-27, 1994.

33. Gerald E. Shuman participated in rancher workshops at Pine Bluffs, Wheatland and Douglas. He presented soil quality and economics relating to CRP research.

UTILIZATION OF ANIMAL, MUNICIPAL, AND INDUSTRIAL WASTES ON SEMIARID RANGELANDS HYDROLOGY, SOILS, AND VEGETATION

Author(s) G.E. Schuman, G.W. Frasier, J.D. Reeder and R.H. Hart

Problem

In recent years, cities and industry have begun to consider rangelands as potential sites for disposal of municipal, industrial and animal wastes. Municipal sewage sludge and feedlot animal wastes have been used successfully as fertilizer and mulch on agricultural lands and reclaimed mined lands, but little information is available concerning the application of waste materials to rangelands where incorporation into the soil is not feasible. Surface applications of waste products to rangelands may increase the quantity and quality of forage, and may improve water conservation. However, nutrients and heavy metals from the applied waste products may also degrade surface and subsurface water quality, result in toxic levels of heavy metals in plant tissues, or cause undesirable shifts in plant species composition.

Approach

This study is being conducted at the Central Plains Experimental Range (CPER) near Nunn, CO, on short grass prairie, and at the High Plains Grasslands Research Station (HPGRS) near Cheyenne, WY, on mixed grass prairie. At both sites a series of thirty 9X9-m plots for vegetation/soil evaluations and twenty 3X9-m plots for hydrologic investigations were established. Treatments consisted of surface applications (23 metric tons/ha) of (1) fresh feedlot cattle waste, (2) composted feedlot cattle waste, (3) phosphogypsum, (4) composted sewage sludge, and (5) control (no treatment). Soil samples were collected in 1993 prior to waste application for evaluating baseline soil properties, and in 1994 to assess the effects of waste application on soil properties. Vegetation samples for evaluating forage production/quality and species composition were collected at peak production in 1993 and 1994. Runoff water quality and quantity were evaluated with a rotating boom rainfall simulator in May and August, 1993.

Results

Runoff hydrographs and samples of runoff water, plants and soil are currently being analyzed. In 1993, total plant production was increased by 34-43% with the composted sewage sludge and composted animal waste, reflecting the additions of N and P from these amendments. Increases in total production were due primarily to increases in warm season grasses, and secondarily to increases in fringed sagewort and annual forbs. All four waste amendments increased the production of annual forbs and fringed sagewort, but no amendment affected the production of perennial forbs. In 1994, a drought year, total plant production was suppressed in the phosphogypsum and fresh manure plots due to decreases in the production of warm season grasses and fringed sagewort. Slight increases in total plant production (10%) were noted in the sewage sludge and composted animal waste plots, primarily due to increases in annual forbs in the composted manure plots, and increases in warm season grass production in the sewage sludge plots.

Future plans

We will sample vegetation and soil for a minimum of three more years in order to assess changes in soil properties, subsurface water quality, forage production/quality, and species composition as a result of a one-time waste application.

GRASS: GRAZING RATES AND STRATEGIES STUDY

Author(s)

R.H. Hart and G.E. Schuman

Problem

Claims for the benefits of short-duration rotation grazing systems have received a great deal of publicity and some official recognition by SCS and other agencies. A study was begun in 1982 to evaluate the response of cattle, vegetation and soils to three grazing systems at three stocking rates.

Approach

Crossbred and Hereford steers initially weighing 260 kg grazed native range 2 June-10 August 1994. Strategies included continuous or season-long grazing (C); rotationally deferred grazing in which grazing was deferred on one- fourth of each pasture until 20 July (R); and 8-paddock short-duration rotation grazing (S). Stocking rates in 1994 were 12.7 (light, L), 28.8 (moderate, M) and 38.3 (heavy, H) steer-days/ha. Steers were weighed every 28 days. Peak standing crop (PSC) and biomass remaining after grazing was estimated inside and outside 4 exclosures per pasture 8-12 August. Cover of all plant species, litter and bare ground was estimated with an inclined point quadrat 7-8 July.

Results

Peak standing crops (kg/ha) were CL, 699ab; CM, 696ab; CH, 564b; RM, 782ab; RH, 628ab; SM, 618ab; SH, 876a. PSC of forbs was higher on SH, and PSC of western wheatgrass was higher on CL than on other treatments. Total plant cover averaged 15.9%. Cover of cool-season graminoids, litter and bare ground was 8.4%, 74.9% and 4.0%, respectively, on CL vs. an average of 4.1%, 59.5% and 19.1% on H. Forage utilization was 1, 30 and 31% under L, M and H, respectively. Average daily gains (kg) were CL, 0.96a; CM, 0.83b; CH, 0.71bc; RM, 0.72bc; RH, 0.64cd; SM, 0.73bc; and SH, 0.54d. Cattle gains decreased with increasing stocking rate under all three strategies.

Future plans

The current phase of this study was concluded in 1994. A paper comparing vegetation in the first 2 and the last 2 years of the study has been submitted to the 5th International Rangeland Congress. A manuscript, to be submitted to Journal of Range Management, will be prepared covering vegetation and livestock responses during all 13 years of the study. The study will be redesigned in 1995 by combining the rotationally deferred pastures to form a 24-paddock short-duration pasture under heavy stocking. The revised study will run for at least 6 years.

LONG-TERM GRAZING INTENSITY STUDY, CENTRAL PLAINS EXPERIMENTAL RANGE

Author(s) R.H. Hart and M.M. Ashby

Problem

Studies of the impact of grazing intensity on steer gains and range vegetation seldom last more than a few years. Data is needed on effects over several decades.

Approach

In 1940, a replicated study of 3 grazing intensities was set up at the Central Plains Experimental Range; single pastures remain of light (L), moderate (M) and heavy (H) stocking on summer-long grazing. In 1994, the light, moderate and heavy pastures were stocked at 15, 20 and 30 yearling heifers per 129.6 ha (320 acres), respectively. Heifers weighed 263 kg when grazing began 17 May 1994. Grazing ended 29 July 1994 on L and 12 August on M and H because of near-drought conditions in late July. Heifers were weighed every 4 weeks. Basal and foliar cover of all plant species was estimated with a 10-pin inclined point quadrat at 5, 6, 7, 8 and 9 meters from each of 20 permanent stakes placed in the large exclosure in each pasture, and the same distances from 20 cages outside the exclosure. Peak standing crop (PSC) was estimated for plots distributed over the entire area of each pasture and also for permanent plots located in and out of exclosures in each pasture. Frequency of occurrence of plant species were sampled on exclosure.

Results

Average daily gains (kg) of heifers were L, 1.19; M, 0.73; and H, 0.69. Peak standing crop on the pasture plots was 635, 718 and 462 kg/ha on L, M and H, respectively; after grazing, 570, 509 and 329 kg/ha remained, for utilization of 10, 29 and 29%, respectively. Inside the exclosures, PSC was 781, 780 and 768 kg/ha; immediately outside the exclosures PSC was 714, 632 and 596 kg/ ha of forage under L, M and H, respectively.

Estimates of basal cover (%) were:

	Exclosures	Light	Moderate	Heavy
Bare ground	13.6	23.2	21.3	23.0
Litter	65.0	55.6	57.1	47.6
Blue grama	10.0	6.9	13.1	15.5
Western wheatgrass	0.5	0.0	0.1	0.0
Needleandthread	1.6	0.2	0.0	0.0
Sedges	0.6	0.1	1.0	0.5
Plains pricklypear	1.4	2.4	0.4	0.6
Fringed sagewort	1.5	2.7	0.0	0.0
Total plant cover	18.7	17.1	18.3	19.2

Future plans

This study will be continued indefinitely. Cover will be estimated inside, outside the exclosures and on the plots distributed over the entire area of each pasture in 2000 and 2001. A manuscript comparing 1993-1995 results to earlier results will be prepared.

GRASS CPER: GRAZING STRATEGIES ON SHORTGRASS AT CPER

Author(s)

R.H. Hart and M.M. Ashby

Problem

Large-pasture studies of the impact of grazing strategies on shortgrass prairie are needed.

Approach

Time-controlled rotation grazing was implemented on a 7-paddock layout, each paddock containing 65 ha (160 A). One paddock was sub-divided into 3 equal-sized paddocks; these mimic a 21-paddock layout. An undivided 326-ha (800-A) pasture was grazed season-long. Three-pasture rotationally deferred grazing was implemented on three 152-ha (373-A) pastures, with grazing on one pasture per year deferred until after 6 July (31 July in normal years). Stocking rate was the same as on the moderately-stocked pasture of the long-term grazing intensity study, one yearling heifer/3.25 ha. Heifers grazed from 16 May to 30 September 1994, and were weighed on and off pasture.

Results

Forage production, measured on the rotationally deferred pastures, averaged 410 kg/ha. Average daily gains (kg) were season-long 1.06, time controlled rotation 1.08, and rotationally deferred 0.95, with no differences among strategies.

Future plans

The study will be continued for at least 12 years. Two exclosures will be installed in each of the six 65-ha paddocks, and four in each of the three 21.7-ha paddocks (simulated 21-paddock layout). Four exclosures will be installed in each of the three rotationally-deferred pastures, and twelve in the season-long pasture. Peak standing crop by species will be determined by clipping in two quadrats per exclosure each year. Exclosures will be moved a few meters each year, but will remain in the same vicinity, on the same range site. A permanent 50-m transect will be located in the vicinity of alternate exclosures. Basal cover will be determined by 10-pin point quadrat at each meter mark along each transect. Heifers will be weighed on and off the study, and gains related to grazing pressure.

GRIPES: GRAZING RANGE AND IMPROVED PASTURE EXPERIMENT ON SHORTGRASS

Author(s)

R.H. Hart and D.T. Booth

Problem

Costs of cattle production could be reduced if the grazing season could be extended, by grazing complementary pastures in spring and/or fall, before and after the grazing season on shortgrass rangeland.

Approach

Two pastures of 16 ha each, containing dense, uniform stands of four-wing saltbush, will be fenced off. One will be stocked at 1 heifer per 2 ha (light stocking) and the other at 1 heifer per 1.6 ha (moderate stocking). Grazing will begin in April and end when regrowth of saltbush begins. Grazing will resume in the fall when cattle come off rangeland and continue until the desired degree of use on saltbush has been achieved. Twenty-one hectares each of 'Bezoisky Select' Russian wildrye and 'Hycrest' wheatgrass were seeded and fenced. One 8-ha pasture (light stocking) and one 6-ha pasture (moderate stocking) of each grass will be grazed both spring and fall. One 4-ha pasture (light stocking) and one 3-ha pasture (moderate stocking) of wheatgrass will be grazed in spring, followed by grazing of the same sized pastures of wildrye in the fall. Each pasture will be stocked with 5 yearling heifers. All heifers will graze shortgrass range at a moderate stocking rate in the summer. Cattle will be weighed on and off each pasture type. Production and use of each range or pasture type will be estimated by the usual methods.

Results

Good stands of 'Hycrest' wheatgrass were obtained. Stands of 'Bezoisk Select' wildrye were satisfactory initially, but summer drought reduced them below satisfactory levels. The wildrye was reseeded after soil temperatures were low enough to ensure seed dormancy until spring. Fencing was begun.

Future plans

Fencing will be completed and additional water tanks installed in 1995. If satisfactory stands of wildrye are achieved, grazing will begin in 1996. The study will continue for 6 years. Grazing pressure-gain curves will be constructed for each pasture type, and possible interactions between grazing pressures on successive pasture types will be investigated.

MONITORING RANCH-SCALE TIME-CONTROLLED GRAZING SYSTEMS

Author(s) R.H. Hart

Problem

Some producers and action-agency personnel have expressed doubts about the applicability of our grazing systems research, because paddock sizes and numbers are smaller than in most ranch-scale systems.

Approach

In 1990, the HR Land Co. established a 47-paddock time-controlled rotation grazing system on about 2225 ha (5500 A) of rangeland (R) and crested wheatgrass (CW) pasture east of Cheyenne. We established six 50-m cover transects in three paddocks of the system and placed an exclosure near each transect. Similar transects and exclosures were placed on adjacent land, grazed seasonlong, of the Wyoming Hereford Ranch (WHR) and Hirsig's ranch. Peak standing crop and utilization on WHR and the HR Land Co. were estimated on 17 August, by clipping as on GRASS above. The pastures on the Hirsig ranch were not grazed in 1994, so only PSC was estimated. Because of the drought, cover was not estimated in 1994.

Results

Production and utilization were:

	HR Land Co.			WHR	
	Range	Crested wheat-grass	Range	Crested wheat-grass	Hirsig Range
Production, kg/ha					
Warm-season grasses	210	299	215	455	178
Cool-season grasses	284	323	366	544	133
Sedges	81	0	139	0	81
Forbs	77	366	107	849	23
Utilization, %					0

FUTURE PLANS: Monitoring will continue on all three ranches for as long as present management continues. We will request information on stocking rates, grazing seasons and gains from the three landowners, and share our findings with them.

NASTY: NUTRIENT ACCUMULATION NEAR STOCKWATER--TEST OF YIELD

Author(s) R.H. Hart and G.E. Schuman

Problem

Increased forage production and shifts in botanical composition of vegetation near stockwater tanks suggest accumulation of nitrogen as a result of increased cattle defecation near water.

Approach

On GRASS and HR Land Co, two exclosures were placed 12.5 and 25 m from stockwater tanks which served 1, 2, 4, 8, or 16 paddocks arranged radially around the tank, and 50 m from the tank serving 16 paddocks. Average production from the exclosures used to estimate forage production and utilization on the same experiments served as checks. On 15 August, herbage was clipped from two 0.2-m^2 quadrats in each exclosure and separated into blue grama (Bogr), western wheatgrass (Pasm), needleandthread (Stco), prairie junegrass (Kocr), other grasses, sedges, fringed sagewort (Arfr), and other forbs and half-shrubs.

Results

Forage production (kg/ha) at peak standing crop was:

Pad-Dist,						Other				
docks	m	Bogr	Pasm	Stco	Kocr	grass	Sedge	Arfr	Forbs	Total
1	12.5	290	193	20	127	5	0	3	69	708
	25	177	187	0	59	0	8	0	16	446
2	12.5	51	424	0	0	19	2	3	65	563
	25	89	305	8	6	0	0	118	150	675
4	12.5	242	123	27	5	45	4	125	117	688
	25	99	99	67	26	0	0	103	16	410
8	12.5	342	392	0	0	0	0	6	253	993
	25	183	84	15	166	7	0	41	203	700
	check	204	102	18	66	6	38	89	170	692
16	12.5	537	158	0	239	145	0	23	413	1514
	25	493	83	0	385	70	36	30	34	1131
	50	325	67	0	38	24	14	8	81	558
	check	210	168	59	57	0	81	0	77	652

At 12.5 m from the tanks, total production increased over the check in 8 or 16 paddocks; Pasm and Bogr production increased in 1, 2 or 8 paddocks; and forb production increased in 16 paddocks, indicating N accumulation. N concentration of herbage did not increase (mean = 1.09%).

Future plans

For the next two years, exclosures will be placed at 12.5, 25 and 50 m from the water tanks, with 2 replications of each number of paddocks. If technical assistance is available, soil cores will be taken from each exclosure, and total and nitrate N, P and K will be determined; depths of cores will be determined later.

MODELLING PLANT AND ANIMAL RESPONSES ON RANGE

Author(s) R.H. Hart, J.D. Hanson[1] and E. Bainter[2]

Problem

Models are needed which are simple enough to run on desk-top computers with inputs readily available to the livestock producer, but complete enough to aid decision-making in livestock management.

Approach

The original STEERISK spreadsheet was suitable for semi-arid rangeland with predominantly spring and summer precipitation in the Central Great Plains. Simple equations described the impact of management variables on the parameters of STEERISK. We tested the feasibility of using SPUR II to re-parameterize STEERISK for other rangeland locations around the western US. SPUR II appeared to over-estimate forage production on a Texas site and the influence of forage digestibility on steer intake and gains on all sites, and to under-estimate weight loss when little forage was available. Therefore we decided to use Soil Conservation Service estimates of forage production on major range sites in years of above average, average and below average production, rather than SPUR II estimates. Everett Bainter, State Range Conservationist for Wyoming, was contacted for assistance.

Results

Forage production estimates for range sites in all Wyoming MLRA's were obtained. Data from GRASS and the CPER long-term grazing intensity study is being examined to determine effects of initial weight, sex and breed of cattle on the parameters of the grazing pressure x gain equations for shortgrass and mixed-grass rangelands. These effects will be incorporated in the STEERISKIER (STEERISK Intended for Every Region) spreadsheet.

Future plans

STEERISKIER will be described in a journal article and one or more articles in producer magazines, and will be made available on diskette to interested customers.

[1]USDA, ARS, Great Plains Systems Research, Fort Collins, CO;
[2]USDA, Natural Resource Conservation Service, Casper, WY

CHEW: CALF HUSBANDRY AFTER EARLY WEANING CREW: COW RESPONSE TO EARLY WEANING

Author(s) R.H. Hart and J. W. Waggoner Jr.[1]

Problem

Calves usually are weaned at 180 to 210 days old, in September or October. By this time amount and quality of forage is so low that weaned calves make little or no gain, and cows are slow to regain any weight lost during nursing. If calves were weaned earlier, any reduction in calkf weight gain might be compensated for by gain of cows, reducing cost of winter feed for cows.

Approach

Two 88-ha native range pastures were stocked at 4.19 ha/cow pair (moderate SR, M), and two 72-ha range pastures at 3.43 ha/cow (heavy SR, H) on 9 Jun 1994. Each pasture contained 21 cow-calf pairs. Because of severe early summer drought, all cows and calves were removed 31 August 1994, and all calves were weaned at this time. Cattle were weighed every 28 days. Forage production (PSC) on CREW and SHAG was estimated on 16 and 18 Aug, 1994, by the methods described under GRASS above. Correlation of meter readings and PSC (r^2) was 0.90.

Results

Mean PSC on CREW pastures was 756 kg/ha; CHEW pastures were not grazed so production was not estimated. Average daily gains (kg) of cows were M, 0.71a and H, 0.46b. Calf gains averaged 1.00 kg, with no difference between stocking rates. Because cattle were removed and calves were weaned at the same time on the pastures intended for summer and for fall weaning, these pastures effectively served as replications of stocking rate. This provided an opportunity to compare variance between pastures or replications, for replications x stocking rates (the conventional error term, and among cattle within pastures, the error term recommended by Conniffe, 1976, Conniffe, D. 1976. A comparison between and within herd variance in grazing experiments. Irish J. Agric. Res. 15:39-46). Analyses of variance were:

	Mean square	
	Cows	Calves
Replications	0.8201	0.1801
Stocking rate	6.5968	0.0967
Reps x stocking rates	2.1568	0.0192
Animals within pastures	0.2937	0.0916

Animals within pastures were a greater source of variation in calf weights than the rep x stocking rate interaction, but not in cow weights. However, variations in calf weights from all sources were very small.

Future plans

This study will be continued for two more years under approximately the same management and stocking rates. If funding is available, a graduate student will observe activity patterns of unweaned and weaned calves and will assist in interpretation of data and preparation of a manuscript, to include economic analysis of the results.

[1]Dept. of Range Management, University of Wyoming, Laramie, WY

SHAG: SUPPLEMENTING HEIFERS FOR ACCELERATED GROWTH

Author(s) R.H. Hart and J.W. Waggoner Jr.[1]

Problem

For successful calving as 2-year-olds, British-breed heifers should weigh about 300 kg when first bred and 400 kg at delivery of their first calf. If these weights are not achieved, first calving may be delayed, delivery may be difficult, and condition of the heifer may be so reduced that rebreeding for the second calf may be unsuccessful. All these events increase costs and reduce profits.

Approach

Two native range pastures of 36 ha each were stocked with 19 yearling heifers (initial weight 283 kg) each for a stocking rate of 1.89 ha/head. Pastures were grazed 8 June-30 August 1994. Heifers on one pasture were supplemented with high-energy blocks containing 15% crude protein. Supplement blocks were supplied ad lib throughout the grazing season, and supplement consumption was determined. Heifers were weighed about every 28 days. Heifers were exposed to bulls at 15 months of age. Subsequent breeding and calving performance will be related to treatment and gains. Forage production (PSC) on CREW and SHAG was estimated on 16 and 18 Aug, 1994, by the methods described under GRASS above. Correlation of meter readings and PSC (r^2) was 0.90.

Results

Mean peak standing crop (PSC) on SHAG was 756 kg/ha. Heifers gained 0.74 kg/day without supplement and 0.71 kg/day with supplement; the difference was not significant. Mean weight on 30 August was 347 kg. Even though stocking rate and grazing pressure were higher than in 1991 or 1992, supplementation still had no effect on gains. Apparently supplement substituted for forage rather than supplementing it.

Future plans

The study will continue for one more year with supplement available ad lib to the supplemented heifers; supplement consumption will be measured.

[1]Dept. of Range Management, University of Wyoming, Laramie, WY

LAPEL: LAMB ADG AND PHOTOSENSITIZATION EXPERIMENT ON LEGUMES

Author(s)

R.H. Hart

Problem

Cicer milkvetch is a productive and persistent legume for irrigated pastures, but some investigators have reported that sheep on cicer pastures become photosensitive.

Approach

Two 4-ha pastures were leveled and corrugated for irrigation. One was seeded to 'Monarch' cicer and 'Regar' bromegrass and the other to 'Ranger' alfalfa and 'Regar' brome. After establishment, the pastures will be subdivided and rotationally grazed with weaned lambs. Gains and photosensitivity will be determined. Later, pastures will be further subdivided and grazed at different stocking rates to quantify the impact of stocking rate on gain and photosensitivity.

Results

A good stand of alfalfa-brome was achieved but the cicer seeding failed completely. Very few plants emerged and none survived. Irrigation difficulties were partly responsible; we continued to have problems getting even distribution of water across the cicer pasture.

Future plans

In 1995, we will seed cicer and brome in another pasture, currently in alfalfa and creeping meadow foxtail, where water distribution has not been a problem. Once established, the pastures will be grazed three to four years with sheep on loan from the UW research station at Archer, WY.

THE INFLUENCE OF POST-HARVEST AND PRE-PLANTING SEED TREATMENT ON SAGEBRUSH SEEDLING VIGOR

Author(s) D.T. Booth, Y. Bai[1] and E.E. Roos[2]

Problem

Debearders are machines developed to remove grain from the seed head of bearded (awned) plants such as barley or wheat. They consist of rotating and fixed tines enclosed in a cylinder and set so materials fed into one end of the cylinder pass through the machine to the opposite end. In passage the material is vigorously rubbed by the tines. Commercial seedsmen use debearders to rub sagebrush seed from seed heads in harvested material. Some buyers and seedsmen have suggested this process damages sagebrush seeds.

Approach

Wyoming big sagebrush seed material was harvested in October 1993 from two Wyoming locations. It was stored in woven polypropylene bags in an unheated warehouse or 4.5 months, then processed with a 48-inch debearder at standard settings and instrumented with temperature and humidity sensors. During each run we fed approximately 45 lb of seed material into the debearder with the outlet door closed, then collected samples through the outlet door at 2, 4, 6, 8 and 10 minutes. We then measured the moisture content (dry wt. basis) of samples, the number of undamaged seeds, and the number of seeds without pericarp (residual fruit wall). We measured the length of stems in the material as an index to processing severity. We also tested seed germination, germination rate and seedling vigor.

Results

Temperatures and relative humidity inside the debearder increased with processing time but this had no effect on the moisture content of seed materials. The longer the seeds were in the machine, the more severe the treatment; but, we found no affect to seed quality except that the number of seeds without pericarp increased. The number of undamaged seeds was not different between 2 and 10 minutes in the machine. To date we have found no reason why seedsmen should not continue to use properly adjusted debearders to process sagebrush seed.

Future plans

We will study the effect of pericarp removal; and, the influence of pre-planting seed moisture management on germination and seedling vigor.

[1]Dept. of Plant, Soil and Insect Sciences, University of Wyoming, Laramie, WY
[2]USDA-ARS, National Seed Storage Lab., Fort Collins, CO

THE INFLUENCE OF IMBIBITION TEMPERATURE ON PROTEINS IN WINTERFAT SEEDS

Author(s) D.T. Booth, R.H. Abernethy[1] and R. Augustrina[1]

Problem

The transition from dry to moist tissues that occurs when seeds take up water (imbibe) is a time of stress. Imbibition temperature is one risk factor since imbibition outside the optimum temperature range can significantly decrease seedling vigor. An understanding of why and how imbibition temperature influences vigor would contribute to better cultural methods for many plants by allowing formulation of specific imbibition techniques for maximum seedling vigor. We suspect that optimum imbibition temperatures reflect the mother-plant environment, age of the seed, and genetics. These factors may exert their influence through the proteins of the embryo, particularly mitochondrial proteins. The mitochondria is the cell organelle where respiration occurs and protein differences in mitochondrial membranes could influence respiration efficiency.

Approach

We measured winterfat seedling vigor after the seeds were imbibed at temperatures between 5 and 20°C. We are now analyzing mitochondrial proteins from some of the same seed collections and we are using an electron microscope to study mitochondrial structure. Winterfat ecotypes identified as having a divergence in their imbibition temperature / seed vigor response, are being grown in a common garden at Cheyenne. We hope these plants will produce seed that will allow us to separate the effects of climate and ecotype on the mitochondria.

Results

Winterfat seed collected in Cheyenne and tested after 24 months of refrigerated storage at 5°C had an optimum imbibition temperature of 0°C (mean seedling axil lengths: 0°C = 51 mm, 5°C = 48 mm, 20°C = 27 mm). However, seeds from the same plants which were harvested in 1993 and tested within 9 months had greater vigor and a positive response to warm imbibition temperatures (5°C = 77 mm, 20°C = 82 mm). Indications are that seed age influences the optimum imbibition temperature and that storage at 5°C did not protect winterfat seeds from the effects of time.

Future plans

We will continue ongoing work but with particular attention to changes that can occur in dry seeds stored at 5°C.

[1]Dept. of Plant, Soil and Insect Sciences, University of Wyoming, Laramie, WY

CASED-HOLE PUNCH SEEDER

Author(s)

D.T. Booth

Problem

Most direct-seeded shrubs die during their first growing season, usually due to an inability of seedlings to obtain needed moisture. To make direct seeding practical, we need to create seed microsites that provide more moisture while reducing seedling moisture needs. Punch planting is a sowing method that could increase seeding success because it places seeds at the bottom of open holes punched deeper into the soil than the normal planting depth. The advantages are that (1) moisture, temperature, and the concentration of soil salts are usually more desirable than at the soil surface, (2) seedlings avoid soil crusts, and (3) are more protected from freezing, wind, and other environmental stresses. However, punch planting has not been practical because punched holes sluff and cover the seed with too much soil.

Approach

I invented the Cased-Hole Punch Seeder (CHPS) and seeding technique to make punch planting practical. The CHPS prevents sluffing by casing, and seeding, punched holes. The casing projects above the soil surface to provide a protective environment above and below the soil surface. CHPS is being tested for establishment and survival of shrubs and other dicots seeded in different years and situations. This year's study was the Happy Jack Highway study which was seeded fall 1993 on road-cuts in the Medicine Bow National Forest where previous revegetation had failed. Bitterbrush was spot seeded into terraces formed in the decomposed granite slopes. The study was repeated on 3 different road-cuts using 80 pairs of seed spots (CHPS and the standard method) at each site. Two seeds were sown at each spot. The number of spots with live seedlings were counted monthly through the growing season.

Results

The total number of seed spots with live seedlings during the summer of 1994 were as follows:

DATE	STD METHOD	CHPS
4 May	1	160
6 June	49	157
5 July	11	75
28 July	8	69
16 Sept	5	63

Future plans

We want to improve survival to take full advantage of the superior establishment from CHPS. The CHPS technique has been modified and tests of these modifications are part of new studies seeded fall 1994.

GLOBAL CHANGE AND IMPLICATIONS FOR RANGELANDS

Author(s) J.A. Morgan, D.R. LeCain, J.J. Read, H.W. Hunt[1], and W.G. Knight[2]

Problem

Atmospheric CO_2 concentrations have been rising for more than a century, and are projected to continue rising well into the next century, with a doubling over present levels expected by mid- to late- 21st century. Work primarily with crop species has indicated increased atmospheric CO_2 concentrations can enhance plant growth through increased photosynthesis, although the magnitude of this response varies considerably with the environment and the particular species. Current information suggests that cool-season (C_3) plants may respond more to CO_2, and that warm-season (C_4) plants will only show positive growth responses to CO_2 when water is limiting. An understanding of how prairie grasses may respond to long-term growth at elevated CO_2 will be required in order to intelligently manage rangelands.

Approach

Two grasses in the eastern Colorado shortgrass prairie of major importance for grazing livestock and wildlife are western wheatgrass, a cool-season (C_3) grass, and blue grama, a warm-season (C_4) grass. In an effort to anticipate how global changes will influence the productivity and species composition of the shortgrass prairie, we conducted growth chamber experiments to examine how CO_2 enrichment affects photosynthesis, growth and related physiological characteristics of these and other important prairie grasses. In one study, plants were grown under deficit watering regimes to simulate the characteristic water-limiting environment of the prairie. In another study , six warm-season grasses were studied under favorable water and nutrient availability.

Results

In western wheatgrass and blue grama plants grown under water-deficits, photosynthesis and growth were enhanced similarly when CO_2 concentrations were doubled from the present concentration of 350 parts per million (ppm) to 700 ppm. Under well-watered conditions, photosynthesis of six warm-season grasses were all stimulated by increasing CO_2 concentrations, but only half of the species showed enhanced growth at the higher CO_2. All plants whose growth was stimulated by CO_2 enrichment had reduced tissue N concentrations. These results suggest that growth of both C_3 and C_4 prairie grasses will be enhanced in future CO_2-enriched atmospheres in severely water-limited environments, although forage quality may decline, and C_3 grasses may respond relatively more to CO_2 than some C_4 grasses when water is readily available.

Future plans

Results from the above experiments are going to be used in computer simulation models to determine among other things, how increased atmospheric CO_2 will influence (a) above- and below-ground partitioning of plant biomass and nutrients on the prairie, (b) competition between C_3 and C_4 prairie grasses, and (c) productivity and nutrient composition of native grasses. Another experiment will be conducted to determine why growth of some warm-season C_4 grasses responds more than others to CO_2 enrichment. In particular, we will be examing how production of various C_4 photosynthetic enzymes is altered in plants grown in CO_2-enriched atmosphere.

[1]Dept. of Rangeland Ecosystem Science, CSU. [2]Front Range Community College, Ft. Collins, CO.

RANGELAND ALFALFA: GENETICS, PHYSIOLOGY & MANAGEMENT

Author(s) J.A. Morgan, G.E. Schuman, R.H. Hart, K.H. Asay[1], and D.A. Johnson[1]

Problem

Productivity of the short-grass prairie of the USA is limited primarily by water and N. Since N fertilization of rangelands is not economically feasible, the possibility of introducing N-fixing legumes into the prairie should be investigated as a means for improving the quality and quantity of forage. Incorporating legumes into semi-arid rangelands will be difficult given the characteristic low rainfall of this region. There is limited evidence that grazed alfalfa could become an important component of some ranching operations, although little information on management options is available, and there are only a few choices of adapted cultivars.

Approach

Three field experiments were begun at the USDA-ARS High Plains Grassland Research Station in Cheyenne, WY. In a genetics study, 80 cultivars/accessions of alfalfa were transplanted and established into ten replication blocks. Beginning in 1995, these plants will be grazed for several years and cultivars evaluated based primarily on long-term persistence. In a related physiology/genetics study, 15 cultivars/accessions representing much of the diversity in the genetics study were established in field plots, and will be examined in ensuing years for variability in physiological traits related to persistence. Results from this second study will help identify persistent cultivars in the genetics study, some of which will then be used in the development of a grazing tolerant cultivar for western rangelands. In a third study, alfalfa/grass cultivars were seeded alternately in rows of variable width to evaluate optimum row spacing and different alfalfa/grass combinations for forage production.

Results

All of the field plots were established satisfactorily. Emergence in the competition study was only fair, so portions of the plots were re-planted, resulting in good stands by autumn. No experimental data were collected in this establishment year.

Future plans

Treatments and management of the plots will continue in 1995. Grazing will commence on the genetics study, and plots will begin to be evaluated for persistence and growth characteristics. Two clipping regimes will begin on the physiology/genetics study. Persistence will be evaluated in relation to treatment effects on soil and plant water relations, and the accumulation of carbohydrate and nitrogen compounds in below-ground storage organs. In the competition study, monitoring of growth, water relations and persistence will begin on the different alfalfa-grass-row spacing combinations. The results from all three studies will be used to develop new cultivars and management concepts for grazing alfalfa in grass mixtures and in western rangelands.

[1]USDA-ARS Forage and Range Research, Logan, UT

IMPACTS OF ANIMAL, MUNICIPAL, AND INDUSTRIAL WASTE APPLICATION ON SEMIARID RANGELAND HYDROLOGY

Author(s) G.W. Frasier, G.E. Schuman, J. Reeder and R.H. Hart

Problem

Rangelands are potential sites for disposal of animal, municipal, and industrial wastes. Surface application of these materials to rangelands where soil incorporation is not feasible poses potential problems with the infiltration/runoff characteristics of an area.

Approach

This study is conducted to evaluate the hydrologic effects of applying animal, municipal, and industrial wastes on native shortgrass rangeland sites at the Central Plains Experimental Range (CPER) near Nunn, CO, and at the High Plains Grasslands Research Station, Cheyenne, WY. Fresh animal waste, composted animal waste, composted sewage sludge, phosphogypsum (an industrial waste product) and control (no treatment) were applied at a rate of 23 metric tons/ha to individual 3-x 10-m plots, 4 replications per site. A rotating boom rainfall simulator was used to evaluate the runoff water quantity. Half of the plots were evaluated 3 days after application in May 1993 and all plots were reevaluated in August 1993.

Results

Data analysis of the rainfall simulator runoff quantities were completed in 1994. At the time of application (May 1993), the equilibrium runoff at CPER from the fresh animal waste and the composted sewage sludge treatments were less than from the control. The runoff from the other treatments were not different than the control. At HPGRS runoff from the control was less than the other treatments. In August the runoff at CPER from the fresh animal waste (38%) and composted sewage sludge (42%) was less than the control (62%) but the phosphogypsum was greater (75%). At HPGRS only the phosphogypsum treatment had higher runoff (35%) than the control (19%).

Equilibrium runoff rates (%)(mean ± std.div.) from a 45 minute rainfall simulator run.

		Treatment				
Site	Test Period	Phospho-gypsum	Fresh Animal Waste	Composted Animal Waste	Composted Sewage Sludge	Control
		(%)	(%)	(%)	(%)	(%)
CPER	May	52±8	38±3	43±15	45±2	56±12
	August	75±15	38±6	58±23	42±12	62±13
HPGRS	May	46±13	56±13	40±7	32±4	23±8
	August	35±16	18±8	20±16	13±92	19±8

Future Plans

All plots will be rerun with the rainfall simulator in 1995 to evaluate the changes in infiltration/runoff that have occurred with time.

GRAZING IMPACTS ON THE HYDROLOGY, SEDIMENT MOVEMENT AND NUTRIENT BALANCE IN THE RIPARIAN ZONE

Author(s)

G. W. Frasier, G. E. Schuman, M.J. Trlica[1], W.W. Leininger[1], J.D. Stednick[2], J.L. Smith[3], C. Corley[1] and R. Pearce[1]

Problem

Erosion and sediment production from semiarid and arid rangelands threatens more miles of stream in the Western United States than any other source of nonpoint pollution. During high precipitation events, nutrient laden sediments from uplands may be transported to riparian zones below. The riparian ecosystem is the last barrier to trap sediment and nutrients before they reach the streams. It is not known how management of these systems affect their ability to reduce this nonpoint pollution.

Approach

The study was conducted along a mountain riparian zone in the Roosevelt National Forest in northern Colorado in 1993 and 1994. A rotating boom rainfall simulator was used to evaluate the effect of riparian vegetation height on removing sediment from overland flow water. Studies were conducted in 2 riparian vegetative communities: a tufted hairgrass, Kentucky bluegrass and *Carex* spp. association and a community composed of beaked sedge and water sedge. Four 3-x 10-m rainfall simulator plots of 3 vegetation height treatments; clipped to the soil surface, clipped to a 10 cm height, and natural height, were evaluated in each vegetative community each year. Water was applied to each pair of plots until equilibrium runoff was achieved. Following a 30 minute rest period water was applied to the plots with the simulator plus a sediment laden water added to the top of each plot. Two sediment sources were used, a local derived sediment and a ground silica based sediment. Water samples were collected at the lower edge of the plots at periodic intervals for N, P, and sediment analysis. Downslope sediment migration of sand sized particles was measured.

Results

Runoff quantities were not correlated to the vegetation treatment. Total sediment quantities measured at the outlet of the plots were not correlated with vegetative height. Clay sized sediment particles were not trapped in the riparian vegetation. Sand and large silt sized particles traveled less 3 meters irrespective of the vegetation height. The nitrate and ammonium concentrations were less in the runoff water than in the applied water. There was higher phosphorous concentrations in the runoff water than the applied water indicating a source of soluble phosphorus from the decaying plant material which can potentially be transported to the stream.

Future plans

Studies will be directed toward obtaining a better understanding of the micro-variability of infiltration in the riparian zone and how it can be incorporated into overland flow models.

[1]Dept. of Rangeland Ecology, Colorado State University, Fort Collins, CO
[2]Dept. of Earth Sciences, Colorado State University, Fort Collins, CO
[3]Dept. of Civil Engineering, University of Wyoming, Laramie, WY

LONG-TERM GRAZING IMPACTS ON HYDROLOGIC CHARACTERISTICS OF A NATIVE SHORTGRASS PRAIRIE

Author(s) G.W. Frasier, R.H. Hart and G.E. Schuman

Problem

High intensity grazing by cattle can reduce the infiltration rates of soils causing increased runoff and possibly increased soil erosion on semiarid rangelands. Rainfall simulators can be used to evaluate the hydrologic effects of livestock and their removal from rangeland.

Approach

A rotating boom rainfall simulator was used to evaluate the hydrologic impact of removing cattle from 2 areas with 53 and 12 years of cattle grazing. The study is being conducted on the Central Plains Experimental Range (CPER) near Nunn, CO, and the High Plains Grasslands Research Station (HPGRS) near Cheyenne, WY. Four, 3-x 10-m rainfall simulator plots were established each year for 3 years (1992-1994) at CPER in exclosures for 3 pastures that had been grazed lightly, moderately, and heavily. Two simulator plots were installed in 2 separate pastures in 1993 for each grazing strategy and intensity treatment at HPGRS.

Results

Baseline hydrologic effects of the historic long-term grazing at CPER were measured in August 1992, 2 months after installation of the exclosures. Initial runoff rates ranged from a mean of 11% on the lightly grazed area to 61% for the heavily grazed area. One year after removal of the livestock (1993), no changes were observed in runoff from the light and moderate grazed areas but runoff was less from the previously heavy grazed area. Runoff rates declined more than 50% for all 3 grazing treatments after 2 years but there remained about the same between the previously light and heavy grazed areas. Runoff rates observed in 1993 at HPGRS ranged from 27 to 48% with similar runoff rates among the season long and rotational grazing schemes. Variability in the results among the treatments preclude any definitive conclusions concerning the impact of the 12 years of grazing. Wet-run equilibrium runoff percentages were:

Year	Season Long			8-Pasture Rotational	
	Light	Moderate	Heavy	Moderate	Heavy
	(%)				
Central Plains Experimental Range					
1992	11±9	30±16	61±7	-	-
1993	14±10	35±14	42±6	-	-
1994	5±5	19±8	35±5	-	-
High Plains Grassland Res. Sta.					
1993	38±15	27±12	48±5	27±19	48±14

Future plans

Rainfall simulations will be run in all exclosures in 1996 to further define the changes in infiltration/runoff with time after removal of livestock grazing.

STRATEGIES FOR ESTABLISHING BIG SAGEBRUSH ON DISTURBED RANGELANDS

Author(s) G.E. Schuman, D.T. Booth, J.R. Cockrell[1], and J. Gores[1]

Problem

Wyoming big sagebrush (*Artemesia tridentata* ssp. *wyomingensis*) is one of the most widely distributed shrubs in the region; however, reestablishing it on disturbed and degraded rangelands has proven difficult and expensive. Past experiences of direct seeding of big sagebrush has generally resulted in poor establishment or complete failure and transplantation of nursery grown seedling has proven labor intensive, expensive and has not always been successful. Regulatory agencies and land management agencies may require or desire the reestablishment of big sagebrush because of its importance in wildlife habitat.

Approach

A field study was established to evaluate and define effective seeding strategies for establishment of big sagebrush on degraded and disturbed rangelands. Specific objectives included the evaluation of: (1) efficacy of direct-applied topsoil for enhanced sagebrush establishment through effects on sagebrush seed and VAM inoculum, (2) the value of various mulch types for moisture conservation and seed microsite modification, (3) the effect of competition from concurrently seeded herbaceous species on the establishment of big sagebrush, and (4) the value of initially establishing fourwing saltbush as a pioneer species for later recruitment of sagebrush.

Results

Topsoil source, mulch type and herbaceous species competition all significantly influenced first and second year sagebrush seedling establishment from a single seeding in February 1992. Fresh topsoil had twice as many sagebrush seedlings established than did stockpiled topsoil. This treatment response continued through 1994 and is not the result of natural seed dispersal or the topsoil acting as a seed bank since the control plots show no sagebrush establishment. Mulch also significantly increased seedling establishment; however, differences between the mulch treatments and no mulch was less in 1994. Grass competition continues to result in about one-third less sagebrush seedlings than where no grass competition occurs. At this time we are unable to fully assess whether using fourwing saltbush as a pioneer species is influencing sagebrush establishment. However, sagebrush seedling density on the fourwing saltbush plots is about 50% of that on the plots seeded to sagebrush at the same time the pioneer plots were overseeded with sagebrush (1993).

Future plans

We will continue to evaluate the role of fourwing saltbush as a pioneer plant for establishing big sagebrush and we will also further evaluate the role of VAM on sagebrush establishment.

[1]Graduate Research Assistants, University of Wyoming, Laramie, WY

CARBON AND NITROGEN DYNAMICS IN GRAZED RANGELANDS

Author(s) G.E. Schuman, J.T. Manley[1], J.D. Reeder, R.H. Hart, and J.A. Morgan

Problem

Long-term, heavy stocking rates can influence the surface litter and standing dead components of the aboveground biomass which may result in reduced carbon and nitrogen inputs to the ecosystem.

Approach

Pastures grazed for the past 11 years at a heavy stocking rate under three management schemes were compared to a continuous light stocking rate and to livestock exclosures. The heavy stocking rate (66.7 steer-days/ha) was evaluated under a continuous, rotationally deferred and a short-duration rotation grazing system. To evaluate carbon and nitrogen dynamics of the various grazing treatments soil samples were collected at 0-3.8, 3.8-7.6, 7.6-15, 15-30, 30-45, 45-61, and 61-91 cm depth increments. The soil samples were evaluated for total organic C and N, N-mineralization and respired-C. Large diameter soil cores were taken to assess root biomass.

Results

Soil organic C and N were significantly lower in the exclosure compared to all of the grazing management strategies in the surface 7.6 cm of soil. No differences existed between any of the grazing strategies, except that in 3.8-7.6 cm soil depth the organic C was significantly lower in the continuous light compared to the heavy grazing strategies, but was still significantly greater than the exclosure. Organic C was lower in the exclosure at the 7.6-15 cm depth than all grazing treatments except the rotationally deferred treatment. Soil organic N did not show any differences between treatments at this depth. In the surface 30 cm, where about 80% of the root biomass exists, organic C was 13-31% and organic N 7-21% lower in the exclosures compared to the grazed pastures. This indicates the importance of the surface few centimeters of soil as it relates to C and N cycling in a grassland system.

Future plans

Roots, litter, standing dead and live plant material C and N analysis are complete and data summarization is continuing to enable development of a C and N balance of this ecosystem. Closed top gas exchange chambers will be used this season to evaluate CO_2 sequestration on the various grazing treatments. Long-term (53 years) grazing studies will also be evaluated to determine if similar trends in C and N dynamics are evident.

[1]Graduate Research Assistant, University of Wyoming, Laramie, WY

ROLE OF CICER MILKVETCH IN RANGELAND ECOSYSTEMS

Author(s) G.E. Schuman, S.E. Williams[1], and Z. Zhao[1]

Problem

Cicer milkvetch is a non-bloating legume that can be used for livestock grazing. It is quite tolerant to grazing and has been established on disturbed rangelands by planting and through distribution of seed by wildlife. It has been thought that cicer milkvetch has very specific inoculum requirements in order to nodulate and fix nitrogen. However, visual evidence of the large numbers of plants established by wildlife indicate that these plants are dark green and have adequate available nitrogen even on the very poor and nitrogen deficient soils present at the field location where they exist.

Approach

Cicer milkvetch plants were identified and excavated to evaluate nodule presence/absence and nodule activity. Five cicer milkvetch plants were excavated in May, June, July, and August on a reclaimed mine site in central Wyoming. Soil samples were also collected to the depth of rooting.

Results

Root nodules were found on all plants excavated. The density of root nodules increased with increasing soil depth with the maximum density occurring at about the 30 cm depth. Nodules were actively fixing nitrogen at all depths that nodules were observed. The density of nodules decreased significantly in August and distribution in the profile varied over the growing season. VAM spore counts decreased with increasing soil depth with the greatest spore count being in the surface soil.

Future plans

Efforts are being made to identify the nodule organisms in an effort to better understand the source of inoculum and to evaluate the perceived specificity of cicer milkvetch inoculum.

[1] Department of Plant, Soil, and Insect Sciences, University of Wyoming.

RANGELAND RESOURCES RESEARCH UNIT

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SOIL-PLANT-NUTRIENT RESEARCH UNIT

Ronald F. Follett, Research Leader
Federal Building
301 S. Howes, Room 407
Fort Collins, CO 80522
TEL: (970) 490-8200
FAX: (970) 490-8213

FTS2000: a03rfollett@attmail.com
INTERNET: rfollett@lamar.colostate.edu

MISSION STATEMENT

To develop and evaluate new knowledge required to efficiently manage soil, fertilizer and plant nutrients (emphasis on nitrogen) to achieve optimum crop yields, maximize farm profitability, maintain environmental quality and sustain long-term productivity.

TECHNOLOGY TRANSFER - 1994

Soil-Plant-Nutrient Research Unit

1. Robert Lober and Ron Follett continue to work with the USDA-NRCS in conjunction with the San Luis Valley Research Project (SLV-RP) to transfer technology associated with the use of the NLEAP computer model for both on-farm use and for use by those who advise farmers concerning fertilizer-N management. Results collected thus far from the SLV-RP were presented as a poster at the ASA meetings where several interested users of the NLEAP model discussed their needs in various parts of the U.S. Users who requested and received information include: Coors Brewing Co. (Burley, ID); White Shell Laboratories (Manitoba, Canada); and, The State Agronomist for Washington state.

2. Jim Sharkoff, NRCS cooperator with Robert Lober and Ron Follett for the San Luis Valley Research Project (SLV-RP), presented a project overview to the USDA-NRCS West-Wide Water Quality Coordinator Technology Transfer Workshop, Logan, UT, November 1-4, 1994. Audience consisted of water quality coordinators from NRCS, state extension offices, and the Environmental Protection Agency representing 11 western states.

3. Robert Lober presented information concerning the San Luis Valley Research Project to the Rio Grande Water Conservation District Board Meeting, in Alamosa, CO, November 8, 1994. The audience consisted of local farmers, area farm consultants, USDA-NRCS, USDI-Fish and Wildlife Service, Geographical Survey, and Bureau of Reclamation.

4. As part of an effort to extend information concerning management of N to protect ground-water quality at the international scale, Ron Follett was convener of one of the 43 Special Symposia presented at the 15th World Congress of Soil Science in Acapulco, Mexico, July 10-16, 1994. The audience consisted of scientists from both developed and developing countries around the world.

5. Drs. Follett and Porter presented information concerning the use of ^{15}N isotopes in a long-term field experiment to about 160 participants from 60 countries at the International Symposium on Nuclear and Related Techniques in Soil/Plant Studies on Sustainable Agriculture and Environmental Preservation, sponsored by IAES in Vienna, Austria, October 17-21, 1994.

6. As a follow-up to having helped establish the MOU with the Colorado state office of NRCS, Dr. Follett continues to meet and provide technology transfer input to the Joint ARS/NRCS/CASCD research committee in Colorado at about 6 month intervals.

7. Dr. Follett served to help write the section concerning the use of fertilizer-N in the President's Climate Action Plan and continues to provide input to the USDA Global Change Office, EPA, NRCS, and others concerning the impacts of fertilizer-N use efficiency and nitrous oxide emissions.

8. Hunter, W.J., Follett, R.F. and Cary, J.W. Bioremediation of water containing high levels of nitrate using vegetable oil in bioreactors. Agricultural Research Service Invention Report. (8/22/94). (Invention Report).

9. W.J. Hunter provided information on the NOD+ mutant and provided other assistance to Dennis Senft, ARS Information Office, for an ARS press release titled "Missouri Firm to Sell New Soybean-Boosting Bacteria." The press release was picked up by the Associated Press Wire Service. An unknown number of news articles were based on this press release. Known articles appeared in the Quarterly Report of Selected Research Projects, April 1 to June 30, 1994; in Agricultural Research, 42:(10)31; and in the Illinois Agriculture News, September 2, 1994. (Press Release).

10. W.J. Hunter provided information on the use of vegetable oil in the bioremediation of water containing high levels of nitrate to Dennis Senft, ARS information office, for a possible Future article that would appear in the journal Agricultural Research. (Press Release).

^{15}N UPTAKE AND LEACHING IN A FURROW AND ALTERNATE FURROW /IRRIGATION SYSTEM

Author(s) J. Benjamin, L.K. Porter, H. Duke, L. Ahuja - Co-investigator: G. Butters[1]

Problem

High nitrate levels in groundwater in the Great Plains has been attributed to nitrogen fertilizer applications on cropland. Alternative soil management techniques must be found to allow the use of nitrogen fertilizers on cropland and yet minimize the adverse environmental effects.

Approach

Model simulations of furrow irrigation and band fertilizer position predicted less nitrate leaching if the nitrogen fertilizer is place in a band that is isolated from the flow paths of the irrigation water. An irrigation-nitrogen placement experiment for irrigated corn crop production was established in 1994 at the Agriculture Research, Demonstration, and Education Center (ARDEC) at Fort Collins, Colorado. Two irrigation water placements, alternate furrow and every furrow, and two ^{15}N labeled fertilizer placements, in-furrow and in-row, were tested to determine plant use and nitrate leaching of labeled ^{15}N fertilizer nitrogen and indigenous soil nitrogen. Corn physiological development, above-ground biomass, total nitrogen uptake, corn yield, and yield components were measured during the growing season to determine the effect of the various placement options on corn growth and the availability of the fertilizer nitrogen to the plant. Soil hydraulic properties, water contents before and after an irrigation, and soil profile distribution of the nitrate and ^{15}N at the end of the growing season to determine leaching and provide data for further model development.

Results

Partial analyses of the first year samples has shown that: 1) Little water from the irrigation moved below the 1.8 m soil depth that was considered to be the root zone; 2) Corn above-ground biomass and corn yield were as good with alternate furrow irrigation as with every furrow irrigation; 3) Labeled fertilizer ^{15}N uptake was greater for the in-row placement than for the in-furrow placement for both irrigation placements early in the season; 4) Total nitrogen uptake and ^{15}N uptake early in the season were less from the alternate furrow irrigation treatment with the fertilizer place in the non-irrigated furrow; 5) By the end of the growing season, total nitrogen and ^{15}N uptake were similar among the every-furrow:row placement, every furrow:furrow placement, and alternate-furrow:row placement.

Future plans

The distribution of the residual $^{15}NO_3$ in the soil profiles will be analyzed to determine nitrate leaching from the different irrigations--fertilizer treatments. Total N and ^{15}N analyses will be completed for the final harvest. The experiment will be moved to a new location within the experimental site and continued for 1995. Bromide leaching will also be included in the 1995 study. Data for these two crop years will be utilized for further model development.

[1] Department of Soil and Crop Sciences, Colorado State University.

8. Hunter, W.J., Follett, R.F. and Cary, J.W. Bioremediation of water containing high levels of nitrate using vegetable oil in bioreactors. Agricultural Research Service Invention Report. (8/22/94). (Invention Report).

9. W.J. Hunter provided information on the NOD+ mutant and provided other assistance to Dennis Senft, ARS Information Office, for an ARS press release titled "Missouri Firm to Sell New Soybean-Boosting Bacteria." The press release was picked up by the Associated Press Wire Service. An unknown number of news articles were based on this press release. Known articles appeared in the Quarterly Report of Selected Research Projects, April 1 to June 30, 1994; in Agricultural Research, 42:(10)31; and in the Illinois Agriculture News, September 2, 1994. (Press Release).

10. W.J. Hunter provided information on the use of vegetable oil in the bioremediation of water containing high levels of nitrate to Dennis Senft, ARS information office, for a possible Future article that would appear in the journal Agricultural Research. (Press Release).

^{15}N UPTAKE AND LEACHING IN A FURROW AND ALTERNATE FURROW /IRRIGATION SYSTEM

Author(s) J. Benjamin, L.K. Porter, H. Duke, L. Ahuja - Co-investigator: G. Butters[1]

Problem

High nitrate levels in groundwater in the Great Plains has been attributed to nitrogen fertilizer applications on cropland. Alternative soil management techniques must be found to allow the use of nitrogen fertilizers on cropland and yet minimize the adverse environmental effects.

Approach

Model simulations of furrow irrigation and band fertilizer position predicted less nitrate leaching if the nitrogen fertilizer is place in a band that is isolated from the flow paths of the irrigation water. An irrigation-nitrogen placement experiment for irrigated corn crop production was established in 1994 at the Agriculture Research, Demonstration, and Education Center (ARDEC) at Fort Collins, Colorado. Two irrigation water placements, alternate furrow and every furrow, and two ^{15}N labeled fertilizer placements, in-furrow and in-row, were tested to determine plant use and nitrate leaching of labeled ^{15}N fertilizer nitrogen and indigenous soil nitrogen. Corn physiological development, above-ground biomass, total nitrogen uptake, corn yield, and yield components were measured during the growing season to determine the effect of the various placement options on corn growth and the availability of the fertilizer nitrogen to the plant. Soil hydraulic properties, water contents before and after an irrigation, and soil profile distribution of the nitrate and ^{15}N at the end of the growing season to determine leaching and provide data for further model development.

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Future plans

The distribution of the residual $^{15}NO_3$ in the soil profiles will be analyzed to determine nitrate leaching from the different irrigations--fertilizer treatments. Total N and ^{15}N analyses will be completed for the final harvest. The experiment will be moved to a new location within the experimental site and continued for 1995. Bromide leaching will also be included in the 1995 study. Data for these two crop years will be utilized for further model development.

[1] Department of Soil and Crop Sciences, Colorado State University.

USE OF THE NLEAP MODEL TO DETERMINE EFFECTS OF CLIMATE AND MANAGEMENT

Author(s) R.F. Follett

Problem

Assessment of the Nitrate Leaching and Economic Analysis Package (NLEAP) computer model under many climatic, soil, crop, and management conditions is needed to improve its usefulness. Also, the potential for using the NLEAP model to determine actual effects of climate and management on nitrate leaching need to be evaluated.

Approach

A new computer model called NLEAP was developed to implement theories, methods, and equations that relate to nitrate leaching. For this study, data from a 3-yr field experiment of continuous corn (Zea mays L.) was used; half of the plots were randomly chosen to be either irrigated, based upon calculated potential evapotranspiration, or nonirrigated. Three replications of nitrogen (N) fertility (56, 112, and 224 kg ha^{-1}) were used. Soil was a Hecla sandy loam to loamy sand soil (Pachic Udic Haploborall). NLEAP has been previously calibrated and validated for these soils. This portion of the study specifically addresses using NLEAP to gain additional information concerning climatic and management effects on model predictions of nitrate leaching and to assess the need for additional approaches that may be required to decrease nitrate leaching and to improve fertilizer N-use efficiency.

Results

This study shows that NLEAP is adaptable to data collected for irrigated and nonirrigated conditions on sandy soil for a wide range of N-treatments. Precipitation distribution and amount were different each of the 3 yrs. Calculation of nitrate-N available for leaching using NLEAP provided an excellent indicator of potential nitrate leaching hazard. NLEAP output showed that leaching of residual soil N is very sensitive to early-spring precipitation on these sandy soils. The NLEAP model provided valuable insights concerning relationships among climate, N leaching, and N- and irrigation-management. To obtain optimum yields while minimizing nitrate leaching, this study indicates the need to use soil and plant-tissue testing, post-emergence fertilizer-N application, and modern irrigation-scheduling technology.

Future plans

Future plans are to complete the publication of the results from this study. Future studies will then incorporate the knowledge that has been obtained into the design and implementation of more comprehensive research studies that include additional crops.

POOL SIZES AND DYNAMICS OF SOIL ORGANIC MATTER: USE OF CARBON DATING FOR GREAT PLAINS SOILS

Author(s)

R.F. Follett - Co-investigators: E.A. Paul[1], S. Leavitt[2], A.D. Halvorson[3], G. Peterson[4], and D. Lyon[5]

Problem

Recent interest in soil organic matter (SOM) as a source-sink in global carbon (C) changes results from assessments that a major part of the overall radiative climate forcing in global change is attributed to atmospheric carbon dioxide, of which large quantities are cycled between the atmosphere and agricultural soils. SOM and the C it contains reflect long-term effects of vegetation, soil biota, climate, parent material, time, and the disturbances by human management on ecosystem functioning. Use of carbon-14 dating techniques to determine the longevity of C storage in SOM is an emerging science; especially when applied on a regional basis.

Approach

Archived soil samples, collected from sites in the Great Plains of the USA in 1947/49 were obtained from storage. Field samples were also collected from Akron, CO and Sidney, NE (native grassland vs. long-term cultivation). Additional samples and/or data were obtained for Sterling, CO and Maricopa, AZ in the USA and from Waldheim and Lethbridge in Saskatchewan, Canada. Soil samples were processed by removing recent plant material. Acid hydrolysis on 1- to 3-g of soil sample was by refluxing in 6N HCl for 18h to obtain a resistant SOM fraction (hydrolysis residue) that remained after soluble materials were separated. Carbon age was measured on both hydrolysis residue and the processed soil. Soil-C age, based upon ^{14}C activity, was determined on a tandem-accelerator mass spectrometer at the Univ. of AZ.

Results

Mean residence time (MRT) of C in surface soils (0-15cm) ranged from modern to 1200y for native sites. However, MRT for the 15-30cm depth ranged from 1200 to 2600y (about 1200y older). Cultivated sites at Akron, CO and Sidney, NE were 1100 and 500y older in the 0-10cm depth than were respective nearby native-grassland sites; for both sites the MRT was about 850y older in the 10-20cm depth for cultivated than for the native sites. At Sterling, CO, MRT of soil-C in the 0-10cm depth ranged from 1600y at the summit to only 740y at the toeslope. Thus, soil disturbances by human activities have resulted in loss of younger soil-C. Resistant SOM fractions were observed to be so old that; although of great importance from a soil-structure and nutrient, water and pesticide absorption standpoint; likely, play only a small role in nutrient cycling and global-C issues.

Future plans

Additional site studies are planned that will include cultivated vs native treatments and that will also more thoroughly consider the effects of soil depth on the MRT of soil-C.

[1]Crop & Soil Sciences, MI State Univ., [2]Laboratory of Tree Ring Res., Univ. of AZ, [3]ARS, Mandan, ND, [4]Dept. of Soil and Crop Sci., CO State. Univ., and [5]Panhandle Res. & Ext. Ctr., Univ of NE.

POOL SIZES AND DYNAMICS OF SOIL ORGANIC MATTER: CARBON-13 ISOTOPE CONTENTS OF GREAT PLAINS SOIL AND WHEAT-FALLOW CROPPING SYSTEMS

Author(s) R.F. Follett - Co-investigator: E.A. Paul[1]

Problem

There is currently a strong interest in soil organic matter (SOM) as a source-sink in global carbon (C) cycling between the atmosphere and agricultural soils. Sufficient published information and knowledge of native plant vegetation for the North American Great Plains now exists to begin to use ^{13}C data as a powerful tool for studying SOM dynamics. This is especially so if the data obtained are combined with that from carbon dating.

Approach

Archived soil samples, collected in 1947/49 from native grassland sites throughout the Great Plains of the USA, were obtained from their storage site at the Northern Great Plains Research Center in Mandan, ND. Data was also obtained for soils of the Canadian prairies. Soils sampling from Akron, CO and Sidney, NE included native grassland vs. long-term wheat-fallow cultivation. Visible plant material and inorganic C was removed and the total organic-C and the $^{13}C/^{12}C$ isotope ratio of the SOM determined by C/N analyzer and mass spectrometry. Historical yield records were obtained for both the Akron, CO and the Sidney, NE locations (both long-term experimental sites) for the purpose of estimating amounts and types of crop-residue C that had been returned to the soils at both locations.

Results

The $^{13}C/^{12}C$ isotope ratio of native grassland, expressed as ^{13}C, ranged from -25.2 in the Canadian prairies to -14.9 at Dalhart, TX. This range is the result of historic mixtures of cool (C_3) and warm (C^4) season plant-species and the C-signature that their respective photosynthetic pathways have imparted to the SOM. At Akron, CO and Sidney, NE; the native grassland with an inherent C-signature that resulted from a historic mixture of mostly C^4 with some C_3 species was converted to wheat-fallow. Wheat is a C_3 species with a ^{13}C of about -26. By isotopic ratio techniques and careful measurement of the total-organic soil-C, we have calculated the contribution of small-grain (wheat) residues to the SOM now present on these sites.

Future plans

In this study, we have determined the ^{13}C of Great Plains soils from sites ranging from the Canadian prairies to Texas. Additional site studies are planned that will include cultivated vs native treatments and that will also more thoroughly consider effects of soil depth and the MRT of soil-C (through C-dating). Use of ^{14}C dating for some of these same sites is provided in another report.

[1]Crop & Soil Sciences, MI State Univ.

NITROGEN CYCLING IN A DRYLAND CROPPING SYSTEM USING N15 TRACER

Author(s) R.F. Follett and L.K. Porter - Co-investigator: A.D. Halvorson[1]

Problem

Use of fertilizer-N increases crop yields; however, losses of applied N through leaching and denitrification can result in environmental degradation. Understanding the processes and controls that exist in the soil-plant system to prevent N-losses is needed to better evaluate soil and fertilizer-management options for improved cropping systems.

Approach

Labeled fertilizer N was applied as $K^{15}NO_3$ at two rates (56 and 112 kg N ha^{-1}) each of the first two years to a 4-yr no-till crop sequence (winter-wheat, sorghum, fallow, winter-wheat). Four replications were used. One-third of the plots received labeled fertilizer-N (10% enrichment) both the first and second yrs; one-third received labeled fertilizer N only the first yr and then normal abundance fertilizer N the second yr; and the final one-third of the plots received normal abundance fertilizer-N the first yr and labeled fertilizer N the second yr. Soil cores to 122 cm depth were collected for determination of N derived from fertilizer (Ndff). In addition, soil samples were collected to 10 cm depth for determination of microbial biomass-C, -N, and -^{15}N.

Results

This report deals only with soil measurements, plant measurements are presented in a separate report. A fourth to a third of applied ^{15}N-labeled fertilizer was present in the top 122 cm of soil after 4-yrs. With time, remaining soil-Ndff in the top 122cm of soil was accumulated to the top 10cm. By 3rd yr, 50-70% of soil-Ndff in the 0-122cm depth was located in the top 10cm, with 30-50% still present by 4th yr. This accumulation likely resulted from crop N uptake and residue deposition on the soil surface. Microbial biomass-C and -N increased in the top 10 cm of soil with time; likely because of crop-residue C and N accumulation near the soil surface. In the top 10 cm, biomass-Ndff as a fraction of soil-Ndff, fluctuated widely during the first two yrs before stabilizing. By 3rd and 4th yrs, biomass-Ndff accounted for about 30% of soil-Ndff in the top 10 cm of soil and did not change significantly for up to 440 days. These observations show that, under no-till, biological processes help conserve soil-Ndff.

Future plans

Future plans are to complete the data analyses and publish the interpretation of these and other data collected as part of this experiment.

[1]ARS, Mandan, ND

SOIL-C STORAGE WITHIN SOIL-PROFILES OF THE HISTORICAL GRASSLANDS OF THE USA

Author(s) R.F. Follett and E.G. Pruessner - Co-investigators: J. Kimble[1] and S. Samson[1]

Problem

Large reserves and the potential to sequester large amounts of carbon (C) in soils exists in the historical grasslands (HG) of the USA. These soil are important as a source-sink in global C cycling. Large areas within the HG region are converted from cropland to the Conservation Reserve Program (CRP). Research indicates that CRP enhances C sequestration, but the magnitude is uncertain as is the importance of C gains or losses at deeper soil-profile depths. Another consideration is that CRP contracts begin to expire in 1995; a recent survey, indicates that up to 27 million acres of CRP land may return to production. Thus, much of the C that the CRP program helped sequester is at risk to being recycled back to the atmosphere as CO_2.

Approach

A collaborative effort is initiated with the National Soil Survey Laboratory (NSSL) of the NRCS in Lincoln, NB to collect detailed soil-profile measurements. Careful use of these data, with STATSGO or other data bases, will allow regional estimates of soil-C storage in the HG and the influence of management (cropped vs. CRP vs. native grassland). Soils are being sampled by soil horizon from pits dug to $\geq$ 2m depth at typical sites along precipitation and temperature gradients within the HG region. At each site, a separate pit is excavated for cropped, CRP, and native land use conditions. Sites are in the same map units on similar geomorphic settings, even though the series may change based upon management. Samples collected from each management-site combination are returned to the either Lincoln or Fort Collins analyses. Soil-physical, -mineralogical, -micromorphological, and -chemical characterization will be done by the Lincoln laboratory The Fort Collins laboratory will be responsible for collection of data on above-ground biomass, plant-species characterization, and laboratory analyses for various C-pools (including: total-organic, identifiable plant-material, particulate organic-matter, mineral-associated, and microbial biomass-C). Isotopic analyses for $^{13}C/^{12}C$ ratios and ^{14}C dating will be done on selected samples to better assess issues related to C-sequestration processes and timing.

Results

Sites have been sampled in CO, NE, and IA to obtain the West to East transect. All samples have been returned to the respective laboratories and analyses are underway.

Future plans

Sampling site selection and field collection of samples will be resumed this coming spring. The focus at that time will be upon obtaining a North to South transect.

[1]NRCS, Lincoln, NE.

USE OF THE CHLOROPHYLL METER TO PREDICT N-FERTILIZER REQUIREMENTS OF WINTER WHEAT IN COLORADO

Author(s) R.F. Follett and C.A. Ruele - Co-investigators: A.D. Halvorson[1]

Problem

Spring application of part, or perhaps all, of the N fertilizer to dryland winter wheat may offer advantages to applying fall only N application. A major advantage of spring-N application is that it allows spring evaluation of stand and stored soil moisture before applying N fertilizer. An additional advantage is that of a shorter period of capital tie-up with spring-N application compared to fall fertilization and that spring-applied N may increase both wheat- grain yields and protein content. Measurement of leaf greenness, as an estimate of chlorophyll content, offers an opportunity to evaluate springtime crop-N status and thereby determine the need for additional fertilizer-N application without costly delays.

Approach

Spring vs. fall broadcast fertilizer-N applications (as ammonium nitrate) are being evaluated at rates of 0, 22, 45, 67, and 90 kg N/ha. Additionally, all combinations of split-fall and -spring N-fertilizer application (up to a total of 90 kg N/ha) are being studied. Early spring measurements are collected of chlorophyll meter readings, plant tissue to determine stem nitrate, and soil samples to 122 cm depth for mineral-N (NO_3-N and NH_4-N) when the winter wheat is at the physiological growth stage of Feekes 5.0. Immediately following this spring sampling, the fertilizer-N is applied. At harvest, grain-protein content, fall soil mineral-N, head count, and yield components (kernel- and head-weights and fertile florets/head) are measured.

Results

One year of data has been collected and samples analyzed. Second year field samples are collected and laboratory and data analyses are underway. First-year data show that greater numbers of heads/ha result in larger grain yields, with number of heads at harvest increasing with increasing fertilizer-N rate. Thus, N-fertilization was related to tiller number survival during the first year of the study. Chlorophyll meter readings were correlated to leaf-N content, especially when fall fertilizer-N had been applied. The highest correlation coefficient of grain yield against chlorophyll meter reading was for the fall fertilized treatments and least for spring fertilizer-N treatments with split application treatments having a correlation coefficient that was intermediate.

Future plans

The field experiment with be run for a third year. Laboratory and data analyses from the first two years will continue.

[1]ARS, Mandan, ND

EFFECT OF PARAQUAT AND IRON ON WHEAT STRAW DECOMPOSITION

Author(s) W.J. Hunter - Co-investigator C.S.T. Daughtry

Problem

In recent years it has become increasingly popular to use minimum- or no-till management practices. These procedures depend upon the careful management of crop residues. A residue cover on the field protects the soil from erosion while increasing weed control, water infiltration, water conservation and crop yields. Three studies were conducted. The first study looked at the effect of paraquat on residue decomposition. Recent reports by the Soil Conservation Service suggest that paraquat may accelerate the breakdown of crop residue. The second study looked at the effect of iron chelation on residue decomposition. It may be possible to reduce the loss of beneficial residue cover from the field by slowing the activity of decay fungi through the use of microbial produced iron chelators. The third study, a collaborative effort with Crag Daughtry (USDA in Beltsville), measured the effect residue decomposition has on remote sensing techniques.

Approach

For all studies field dried wheat residue, *Triticum aestivum* cv. Oslo was incubated aerobically in 100 ml serum bottles containing 1 g of residue, 50 g of sand and 10.8 ml of residue buffer. Each serum bottle was inoculated with 1.2 ml of freshly collected soil extract. For the paraquat study treatments were control, paraquat at 100 times the field application rate, and a nitrogen treatment containing an amount of nitrogen equal to that present in the paraquat treatment. For the iron chelator study treatments were 0, 10, 100 and 1,000 µM ethylenediamine di-o-hydroxyphenylacetic acid (EDDHA). Untreated residue was used for the remote sensing study. Incubations were in the dark at 30°C. Residue loss was followed by dry weight change over time. Data was taken at 0, 2, 4, and 8 weeks for the paraquat study; at 0, 2, 4, 8 and 16 weeks for the chelator study; and at 0, 0.5, 1, 2, 4, and 8 weeks for the remote sensing study.

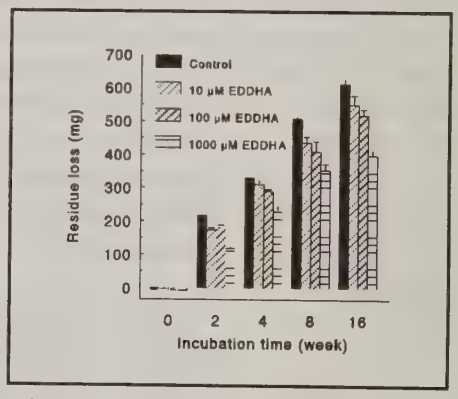


Figure 1. Effect of EDDHA on residue decomposition.

Results

The paraquat treatment did not influence the rate of residue decomposition. The EDDHA treatments all significantly slowed the rate of residue decomposition with the effect increasing with the concentration of chelator (Figure 1). These results suggest that it may be possible to use chelators to slow the rate of residue decomposition. The remote sensing study documented the fluorescence spectra of decomposing wheat residue and demonstrated that the spectra of wheat residue is significantly different from that of soil.

Future plans

No additional studies are planned with paraquat. Additional iron chelators studies will examine the biological chelator produced by *Pseudomonas putida*. The remote sensing data has been submitted for publication.

BIOLOGICAL ACTIVITY OF BRASSINOSTEROID ANALOGS

Author(s)

W.J. Hunter - Co-investigator M.E. Baker

Problem

Brassinolides are steroidal lactones that can show high biological activity. These compounds structurally resemble the naturally occurring brassinosteroids. Brassinolides elicit a broad range of responses in plants. It has been proposed that brassinosteroids represent a sixth class of endogenous plant growth regulator. The effect these compounds have on plant growth and maturity is of potential agricultural importance. The studies are a collaborative effort with Mike Baker at the University of California in San Diego.

Approach

The steroid hormone project has looked at the effect of glycyrrhizic acid, 24-epibrassinolide, 28-homobrassinolide and related compounds on plant growth and development. Plants were grown in the growth chamber in hydroponic growth pouches containing 100 ml of media. Steroids were added to the hydroponic growth media at the start of the study. Measured parameters have included vegetative stage; plant wet and dry weight; root, shoot and internode length; and number of lateral roots.

Results

Results indicate that glycyrrhizic acid has little effect on plant growth and development. However, the two brassinolides have a strong effect, greatly retarding plant development, plant weight, root and shoot elongation, and lateral root development. These effects were observed at concentrations as low as 1 nM. Interestingly, preliminary data suggests that a means of counteracting the negative effects of the brassinolides was observed. In this study a proprietary procedure was found to increase both shoot and root wet weight as well as shoot and root length. Stressed plants are not as sensitive to these compounds as plants grown under more optimal conditions.

Future plans

These studies were initiated several years ago but have not been reported because of difficulties in reproducing the data. It appears that very minor environmental changes greatly influence that effect that these hormones have on plant growth and development. We hope to resolve some of the problems we have had with reproducability and prepare a manuscript for publication sometime in the near future.

BIOREMEDIATION OF HIGH NITRATE WELL WATER BY THE USE OF INNOCUOUS VEGETABLE OIL

Author(s) W.J. Hunter and R.F. Follett

Problem

Nitrate contamination of subsurface waters is a health threat to both humans and farm animals. Agriculture contributes to this problem as nitrate leaches from irrigated farmlands and feedlots into the aquifer. The maximum permissible level for drinking water in the USA has been set at 10 ppm nitrate-N. Many areas exceed this limit. Only about 30% of the water from the South Platte River Aquifer in northern Colorado meets this standard. The objective of this project is to evaluate a method for eliminating nitrate from pumped groundwater. The method uses innocuous vegetable oil as a carbon source to stimulate denitrification. It may be used *in situ* by the injection of oil around the base of a well or it may be used in above ground sand and gravel filters. Because oil is insoluble in water it forms a plume of oil droplets that become trapped by the soil and form, in essence, a filter through which the groundwater flows. Microorganisms, capable of removing nitrate, are naturally present in the vadose zone and water table. The absence of a carbon source normally limits the activity of these denitrifying microorganisms. Vegetable oil provides the needed carbon source, allowing the denitrifying organisms to actively utilize the nitrates presence in the groundwater as a term electron acceptor for anaerobic respiration. The procedure proposed here is unique in two important aspects. First, the carbon source does not dissolve in the water and thus does not move with the water. This allows it to remain in place and act as a filter through which the water moves. Second, the water is being treated only at the point from which it is removed from the aquifer. This is a simpler and less expensive approach than attempting to treat the water as it enters an aquifer as other approaches have suggested.

Approach

Batch experiments have used static bioreactors containing sand as the solid support, buffer solution as the aqueous phase, and soil extract as the source of denitrifers. Experiments using soil columns through which the water is pumped are also underway.

Findings

Studies with static bioreactors show that only a short period of time, 24 to 48 hours, is required for the denitrifying population to begin denitrification with vegetable oil as a sole carbon source and that denitrification proceeds over a wide range of oil and nitrate concentrations. Neither large amounts of oil, up to 120 mg/ml of water, nor nitrate concentrations up to 180 ppm-N interfere with the denitrification. Though denitrification was inhibited at 1000 ppm nitrate. Oil, injected onto 2.5 by 30 cm columns also removed nitrate from flowing water. As much as 10 mls of oil has been injected onto the columns. Water containing as much as 100 ppm nitrate has been denitrified in the columns. And flow rates of up to 650 ml/day have been used. In gas traps placed at the end of the columns N_2 and smaller amounts of N_2O, O_2 and CO_2 were detected. Neither H_2S nor CH_4 were detected. Thus, innocuous vegetable oil may provide the basis for a simple method of nitrate removal.

Future plans

Future work will be directed at expanding the data obtained in CY 94.

SOIL WATER AND OXYGEN CONCENTRATION CONTROLS ON SURFACE-ATMOSPHERE NO AND N_2O EXCHANGE

Author(s) G.L. Hutchinson - Co-Investigator: W.H. Anthony[1]

Problem

N_2O and NO_x ($NO+NO_2$) are trace atmospheric constituents with important functions in various physical and chemical atmospheric and ecosystem processes. Biotic and abiotic reactions in soil is one of the principal sources of these gases. Among major controllers of the soil source, water strongly influences the supply of O_2, as well as the diffusive transport rates of other reactants and products involved in NO_x and N_2O production and consumption processes, thereby influencing not only their rates, but also their product ratios. Separating and characterizing the confounded influences of soil water content on net NO_x and N_2O production in soil is crucial to understanding (and eventually mitigating) their soil-atmosphere exchange.

Approach

In our most recent series of controlled laboratory soil incubation experiments, we monitored rates of CO_2, NO, and N_2O evolution and changes in inorganic N concentrations of soil as a function of O_2 concentration in the presence and absence of added C substrate (glucose) and a nitrification inhibitor (nitrapyrin). The incubation apparatus and procedures were described by Hutchinson and Andre (*Soil Sci. Soc. Am. J.* 53:1068-1074); soil water content was held constant.

Results

Emission of NO and N_2O both varied inversely with O_2 concentration. NO always exceeded N_2O emission, regardless of whether C substrate or nitrapyrin was added. At 21% O_2, added C reduced NO and N_2O emission by immobilizing ammonium, but at 0.0% O_2, C enhanced the rate of denitrification-based emissions by stimulating heterotrophic growth. At intermediate O_2 concentrations, C's primary effect apparently resulted from its reduction of O_2 availability. By comparing the results obtained in the presence and absence of nitrapyrin, we determined that autotrophic nitrifiers were the primary source of NO and N_2O at O_2 concentrations greater than 2%, and heterotrophic organisms were the primary source below 0.2% O_2. The ($NO+N_2O$) yield of nitrification increased with declining O_2 supply, probably because N_2O (and maybe some of the NO) was produced by reduction of product nitrite, which increased as O_2 became limiting. The ($NO+N_2O$) yield of heterotrophic denitrification was much higher but decreased at the lowest O_2 concentration, probably because N_2 became an increasingly important product.

Future plans

Because the Specific Cooperative Agreement supporting the Co-Investigator terminated December 31, 1994, future cooperative activity will be limited to completing an M.S. thesis and manuscript both based on the above results. Results at 0.2% O_2 failed to distinguish between two possible interpretations, so that experiment will be repeated using a newly acquired continuous O_2 monitor. In other experiments planned to further characterize the confounded influences of soil water content, reactant/product diffusion rates, and O_2 supply on net production of N_2O/NO_x in soil, water content will be varied while O_2 concentration is maintained constant.

[1]Cooperative Agricultural Research Center, Prairie View A&M University

NUMERICAL ANALYSIS OF THE PERFORMANCE OF CHAMBERS USED FOR MEASURING SOIL-ATMOSPHERE TRACE GAS EXCHANGE

Author(s) G.L. Hutchinson - Co-Investigators: R.W. Healy[1], G.P. Livingston[2], and R.G. Striegl[1]

Problem

Chambers play a critical role in research concerning surface-atmosphere trace gas exchange, so understanding their performance, accuracy, and limitations is essential to properly interpret published trace gas budgets, to develop and validate trace gas exchange models, and to conduct experimental studies of trace gas exchange processes. Deployment of either a steady-state or non-steady-state chamber inherently perturbs its underlying vertical and horizontal soil gas concentration gradients, thereby altering the surface-atmosphere gas flux that the chamber was intended to measure. Failure to understand and account for that perturbation results in the potential for significant error in estimating the true (pre-deployment) trace gas flux.

Approach

We are using a 3-dimensional time-dependent numerical gas diffusion model to examine non-steady-state chamber feedback processes as a function of atmospheric conditions, soil properties, and source/sink characteristics. Model structure was adapted from an existing USGS model for describing water movement in unsaturated soil. It differs from other models used to investigate chamber performance in that it is 3-dimensional, uses a shorter time step, and specifically includes the chamber headspace in the simulated domain.

Results

Model simulations showed that deployment of a non-steady-state chamber causes a near-instantaneous reduction of near-surface trace gas gradients in soil that determine chamber-measured fluxes. Magnitude of the reduction was strongly dependent on whether the chamber also perturbed atmospheric mixing processes immediately above the surface. Effects of changes in atmospheric interfacial layer thickness, air buoyancy, and mass flow driven by turbulence-induced pressure fluctuations were all considered. The potential for error in chamber-measured trace gas fluxes was also increased by any change in soil properties that enhanced gas diffusion rates, but was independent of the magnitude, distribution, or kinetics of the trace gas source or sink. Detailed sensitivity analyses confirmed that neither the size of spatial and temporal discretizations nor the boundaries of the simulated domain artificially impacted simulation results. Our model is a useful tool for optimizing chamber design and deployment protocol to minimize the potential for measurement errors due to chamber-induced transport disturbances.

Future plans

The analysis of non-steady-state chambers described above will be repeated for steady-state chambers. Following acceptance of a manuscript (already submitted) identifying physical processes that may contribute to chamber-induced measurement error, we plan a follow-on manuscript analyzing the simulated influence of those processes on chamber performance *per se*. We also plan labaratory studies to confirm the simulation results.

[1]Division of Water Resources, USGS, Denver, CO. [2]Earth Systems Science Division, NASA Ames Research Center, Moffett Field, CA.

A DIFFUSION-BASED NONLINEAR REGRESSION MODEL FOR TRACE GAS FLUX ESTIMATION FROM NON-STEADY-STATE CHAMBER CONCENTRATION DATA

Author(s) G.L. Hutchinson - Co-Investigators: G.P. Livingston[1] and H.K. Iyer[2]

Problem

Deployment of a non-steady-state chamber to measure soil-atmosphere exchange of any trace gas inherently perturbs concentration gradients of that gas in underlying soil, thereby altering the flux that the chamber was intended to measure. The resulting nonlinear rate of trace gas accumulation in the chamber headspace is sometimes poorly fit by the linear regression model commonly employed to estimate flux from the chamber concentration data, thus yielding an underestimate of the true (pre-deployment) exchange rate. Other models of chamber concentration vs. time that have been proposed as alternatives are also not founded on gas transport theory, fail to accommodate measurement variabiltiy, and/or are not amenable to testing the statistical significance of the resulting trace gas flux estimates.

Approach

We are developing a nonlinear regression approach to trace gas flux estimation from chamber concentration data that employs a recently derived analytical solution of the 1-dimensional time-dependent gas diffusion equation. Sensitivity of the new flux model to analytical precision and to the number and timing of chamber observations will be determined with SAS simulations using different assumed degrees of nonlinearity in the trace gas accumulation rate. Flux estimates obtained from the model will also be compared with those from linear, quadratic, and exponential models employed by other researchers using data generated for various assumed conditions by our 3-dimensional numerical gas diffusion model, as well as field observations from the literature and from our files.

Results

Results of 3-dimensional numerical model simulations demonstrated that the enhancement of horizontal diffusion by a non-steady-state chamber is mostly overcome by the common practice of inserting its walls at least 5 cm into the soil, thereby justifying use of the 1-dimensional analytical solution. Thus, the model satisfies the important criteria that it should be based on gas transport theory, must accommodate measurement variabiltiy, and must be amenable to significance testing. We have written and tested SAS code for performing the sensitivity studies, which will be run as time and resources become available. We have also accumulated the field and model-generated chamber data describing soil-atmosphere NO, N_2O, CH_4, and CO_2 exchange needed for the model comparisons described above.

Future plans

Following completion of this work, it will be described along with suggested sample allocation strategies in a manuscript to be submitted for publication in the *Journal of Geophysical Research*. We also plan a paper summarizing all our work regarding chamber performance, accuracy, and limitations for presentation at the XII International Symposium on Environmental Biogeochemistry (September, 1995) and for publication in its proceedings.

[1]Earth Systems Science Division, NASA Ames Research Center, Moffett Field, CA.
[2]Statistics Department, Colorado State University.

SEPARATING THE CONTRIBUTIONS OF NITRIFICATION & DENITRIFICATION TO NET NO & N_2O PRODUCTION IN WELL-AERATED SOILS IN THE FIELD

Author(s) G.L. Hutchinson

Problem

Previous research in my laboratory established the relative contributions of nitrifying and denitrifying microorganisms to the biogenic emission of gaseous N oxides (N_2O and NO_x) under a variety of conditions in controlled laboratory soil incubations. These findings could not be confirmed directly on well-aerated soils in natural field environments because the selective microbial inhibitors that were employed are too insoluble or too unstable to ensure uniform distribution and effective inhibition of their target organisms without significant disturbance. Nevertheless, because gaseous N oxides have important functions in many atmospheric and ecosystem processes, it is essential to resolve which microbial N transformations are importantly involved in production and emission of the gases from both undisturbed and agricultural soils in the field.

Approach

Recent literature suggests that nitrifying organisms may be inhibited up to several days by short-term exposure to low concentrations of acetylene, following which they resume pre-exposure activity. Previous attempts to use acetylene to inhibit nitrification in the field assumed that continuous exposure was required, so the gas was injected at depth and allowed to flow (or diffuse) toward the surface. Instead, I propose deploying a chamber on its permanent base one day prior to its use for measuring N oxide exchange, flowing acetylene through it for a period long enough for the gas to diffuse downward throughout the zone of nitrifier activity, and then removing it to allow the acetylene to escape prior to making exchange measurements the following day. Advantages include: (1) no mass flow is required, which disrupts trace gas concentration profiles in soil, (2) gaseous N oxide detection is performed in the absence of acetylene, which interferes in some analytical methods, (3) acetylene's presence is too brief to represent a significant C source to heterotrophic organisms that might metabolize it, and (4) the resumption of nitrifier activity after a short respite ensures a nearly unperturbed supply of denitrification substrate, thereby avoiding the need to add nitrate, which could seriously perturb N cycling dynamics in low-N soils.

Results

The project was only recently initiated. Preliminary modeling results suggest that the time required for diffusion of acetylene throughout the zone of nitrifier activity and to permit its escape following chamber removal should not limit feasibility of the approach described above.

Future plans

Objectives of planned CY 1995 experimental/modeling studies are to determine (1) the effect of environmental conditions and exposure concentration/time on the extent and duration of nitrifier inhibition by exposure to acetylene in the labaoratory, (2) the minimum chamber acetylene concentration and deployment time required to achieve optimum inhibition in the field as a function of soil properties, and (3) the time required for acetylene to escape from soil following removal of its source of supply. In addition, I will confirm that the acetylene does not represent a significant C source to heterotrophic organisms, and that despite a short interruption of the principal source of nitrate, denitrification can occur at a rate similar to that in soil not exposed to acetylene.

OVERCOMING INHERENT SAMPLING AND ANALYTICAL ERRORS UNIQUE TO FIELD MEASUREMENT OF SOIL-ATMOSPHERE NO_x EXCHANGE

Author(s) G.L. Hutchinson - Co-Investigator: E.A. Davidson[1]

Problem

Using chamber methods to measure soil-atmosphere NO_x ($NO+NO_2$) exchange in the field presents unique challenges not encountered in determining other trace gas exchange rates. Most of the NO_x emitted by soil is NO, but in the presence of ambient atmospheric levels of ozone (O_3), some of the emitted NO is oxidized to NO_2, which is strongly sorbed by soil, plant, and chamber surfaces. Resulting sample handling difficulties make immediate in-field analysis of air samples a necessity, but the only commercially available analytical technique suited to this task lacks long-term stability, is sensitive to NO_2 but not NO, exhibits moderate cross-sensitivity to O_3, and has a nonlinear calibration curve. In addition, the efficiency of its in-line CrO_3 converter for oxidizing NO to NO_2 exhibits poorly-defined dependence on relative humidity of the air samples.

Approach

The converter efficiency's dependence on sample relative humidity will be studied in the laboratory using an artificial air stream with variable NO, NO_2, O_3, and H_2O concentrations. In addition, the concentration and matrix of luminol solution (the chemical responsible for the chemiluminescent reaction on which the method is based) will be optimized to yield maximum calibration curve linearity. Protocol for eliminating the potential for measurement error created by ambient atmospheric O_3 captured during chamber deployment, for avoiding the introduction of additional atmospheric O_3 during chamber air sampling, and for overcoming cross-sensitivity of the analytical detector to O_3 will be investigated in the laboratory and then field-tested.

Results

Atmospheric O_3 captured during chamber deployment was rapidly destroyed on soil and chamber surfaces, declining to less than 1 ppbv within 2 min for all soils tested. Rates of NO accumulation measured after a 2-min delay were, therefore, not influenced by O_3. Returning scrubbed sample air to the chamber in a continuous loop prevented introduction of additional atmospheric O_3 during chamber sampling. CrO_3 converter efficiency was near 100% at dew points ranging from 5°C to about 20°C. At lower water vapor concentrations, the efficiency declined precipitously, reaching 0% after long-term exposure to very dry air (<-40°C dew point). The efficiency also declined (but much more slowly) as the dew point increased above 20°C. Protocol developed for adjusting the humidity of field air samples and for using dry gas standards for rapid in-field calibration checks is being tested. Changes to the instrument manufacturer's luminol solution formulation sometimes improved calibration curve linearity at either low or high NO_x concentration, but simultaneously degraded linearity at the opposite end of the curve.

Future plans

We will complete laboratory evaluation of the instrumental method for NO_x analysis, test the resulting recommended protocol for minimizing sampling/analytical errors during NO_x exchange measurement, and submit a journal Note summarizing the results in CY 1995.

[1]Woods Hole Research Center, Woods Hole, MA.

PULSES OF CO_2, NO, & N_2O EMISSIONS FOLLOWING PHYSICAL DISTURBANCE OR WETTING DRY SOIL: MECHANISMS & IMPORTANCE TO C AND N CYCLING

Author(s) G.L. Hutchinson - Co-Investigator: D.C. Reicosky[1]

Problem

Previous research showed that a large pulse of CO_2, NO, and N_2O evolution often occured immediately following wetting of very dry soil. The pulse was too large to be explained by water's well-defined effects on solution-phase and gas-phase transport in soil, and reasons for its occurrence remain unclear. Subsequent research suggested that similar pulses occur following rapid warming of soil exposed to a long period of low temperature, following tillage of partially compacted soil (D.C. Reicosky, unpublished data), and possibly following sudden removal of other environmental limitations on microbial growth and metabolism. Emission rates during such an event may be up to a thousandfold higher than rates preceding or following the pulse, so the quantity of soil C or N lost during its brief duration may exceed the total amount emitted during the much longer periods between times that the soil becomes predisposed to support another emissions pulse in response to the next perturbation. Implications to C and N cycling are obvious.

APPROACH

Experimental and modeling approaches will be used to test the hypothesis that the pulses result from decoupling of consecutive reactions carried out by separate microorganisms with different sensitivities to the offending environmental limitation. This hypothesis is most plausible for explaining nitrifier-induced NO and N_2O pulses; i.e., nitrite produced via ammonium oxidation by *Nitrosomonas* may be chemodenitrified until *Nitrobacter*, which oxidizes nitrite to nitrate, adapts to its elevated substrate supply. For CO_2, NO, and N_2O pulses from other source processes, an explanation must also consider changes in substrate and product transport rates.

Results

Application of our 3-dimensional time-dependent numerical gas diffusion model (described in a separate report) confirmed that the CO_2, NO, and N_2O emission pulses observed in my laboratory and in the field by D.C. Reicosky and were not artifacts of the chamber methods used for their measurement. Preliminary results of other simulations suggest that tillage-induced changes in soil air-filled porosity and gas concentration profiles could account for observed high CO_2 evolution for only 1-2 days, suggesting that an increase in heterotrophic microbial activity was at least partially responsible for the approximatley 3-week enhancement of CO_2 release rates.

Future plans

Selective microbial inhibitors and manipulations of the substrate supply to various microbial groups will be used to characterize their contribution to the pulse of CO_2, NO, and N_2O evolution following temperature, wetting, and physical disturbances in laboratory soil incubation studies. D.C. Reicosky and I also plan additional model simulations to determine what fraction of tillage-enhanced CO_2 evolution is due to physical vs. biological factors, and to define the magnitude, distribution, and kinetics of the biogenic CO_2 source required to make the model continue to fit his field observations after a strictly physical explanation is no longer adequate.

[1]USDA-ARS, Morris, MN.

PARAMETERIZING A PROCESS-LEVEL MODEL OF SOIL-ATMOSPHERE GASEOUS N AND CH_4 EXCHANGE IN SEMI-ARID AGROECOSYSTEMS

Author(s) G.L. Hutchinson and M.F. Vigil - Co-Investigator: J.W. Doran[1]

Problem

Methane (CH_4) and gaseous N oxides (N_2O and NO_x) are radiatively, chemically, and ecologically important trace atmospheric constituents. Microbial processes in soil is a major source of atmospheric N oxides and both a source and sink for atmospheric CH_4, so it is essential to understand exchange of these gases across the soil surface and, if needed, to develop mitigation technologies. Short-term NO_x, N_2O, and CH_4 exchange have recently been measured from several ecosystem types under a variety of soil and climatic conditions around the world, but longer-term studies that yield tenable estimates of total seasonal-to-interannual exchange at a particular site are conspicuously absent from the literature. Assessing the contribution of the net soil source to global atmospheric NO_x, N_2O, and CH_4 budgets is further complicated by its immense temporal and spatial variabiltiy and by the apparent existence of multiple biotic and abiotic soil sources and sinks of the gases, each of which is subject to a different set of controllers.

Approach

Our overall goal is to capture field-measured exchange rates of the three gases in terms of their basic physical, chemical, and biological controllers. Dependence of the fluxes on these controllers will then be described by simulation models parameterized by variables observ-able at multiple scales, which should enhance our predictive understanding of trace gas exchange phenomena across time and space domains larger than the scale of available measurements.

Results

In research conducted on CRP plots at the Central Great Plains Research Station and on native grassland at the Central Plains Experimental Range, observed variability in soil NO and N_2O exchange rates was successfully simulated by the product of a constant that reflected soil N availability, an exponential function of soil temperature, and a two-segment linear function of soil water-filled pore space. Ten- to fifty-fold differences between fluxes measured under widely divergent conditions were reduced to less than a factor of two after normalization to the same soil temperature and water content, and the remaining differences were correlated with measured changes in various soil N availability indices. On two sampling dates when intensive sampling was scheduled to coincide with simultaneous measurement of various proposed soil quality indicators by the Co-Investigator, methods of the two groups compared well, but the soil quality indicators were not well correlated with seasonal/annual soil-atmosphere NO_x, N_2O, and CH_4 exchange.

Future plans

Both field and laboratory experiments are planned to improve understanding of the proposed model constant's dependence on the sizes and transformation rates of identifiable soil N pools and to develop an effective method of adjusting the effect of wetting for existing soil water content prior to the precipitation event, both of which are needed before this approach can be extended over the larger areal and temporal domains to which we think it may apply.

[1]USDA-ARS, Lincoln, Nebraska

CALIBRATION OF NLEAP FOR THE SAN LUIS VALLEY WATER QUALITY DEMONSTRATION PROJECT

Author(s) R.W. Lober and R.F. Follett - Co-investigator: James Sharkoff [1]

Problem

Currently, wells are the primary source of drinking water for humans who live within the San Luis Valley (SLV) of Colorado. Nitrate contamination of local wells in excess of the U.S. Environmental Protection Agency standards of 10 mg l^{-1} nitrate-nitrogen (NO_3-N) are extensively documented in the literature. These elevated ground-water NO_3-N levels are strongly correlated to agricultural practices. Cropping systems in the SLV are intensive, often utilizing significant inputs of N-fertilizer and water. These large inputs, in conjunction with coarse-textured soils and high water tables, increase the risk of ground-water contamination in this area. In cooperation with the USDA Natural Resource Conservation Service (NRCS) Water Quality Demonstration Project, the USDA Agricultural Research Service (ARS) is conducting a project to evaluate and tailor the USDA-ARS NLEAP computer model (Nitrate Leaching and Economic Assessment Package) for use by the NRCS, local farm advisors and farmers in the SLV.

Approach

To tailor the model to local conditions, a study was initiated to assess model data-set utility for the SLV. Two replicated sites were selected to assess model predictive performance using either locally obtained data or NLEAP default data sets. On-farm soil and plant data, plus nearest climate-weather data were collected for replicated plots of *moravian* Barley and *century* Potato. Required farm-management data were collected at each site during the growing season. Numerous on-farm sites are being used to evaluate model performance across varying soil textures and cropping systems in the Valley. Appropriate soil and plant data sets plus farm management inputs were collected for each field and NLEAP simulations are being compared to measured fall residual soil nitrate.

Results

Model prediction of observed fall residual NO_3-N in Barley and Potatoes improved significantly when both local plant and soil data sets were used. Climate data, using locally obtained ET, did not significantly improve model predictive performance for the year evaluated. The model assessment details the importance of tailoring the model to local conditions for accurate estimates of NO_3-N leaching potential in this area. Evaluation of model simulations across soil textures and cropping systems using local soil, crop and climate data sets shows a strong relationship (r^2=0.86) between predicted and observed NO_3-N within the total crop root zone. A t-test of graph slope and intercept was not significantly different than 1 and 0 respectively (α=0.05).

Future plans

Work is underway to expand the local plant data set to include dominant crops currently grown, and crops anticipated to be important in the future. Soil data sets are being upgraded to reflect soils in the region. A climate data set, with local precipitation patterns and ET is being constructed for average, wet and dry years.

[1] USDA-NRCS, San Luis Valley Water Quality Demonstration Project.

USE OF NLEAP IN THE SAN LUIS VALLEY WATER QUALITY DEMONSTRATION PROJECT

Author(s) R.W. Lober and R.F. Follett - Co-investigator: James Sharkoff [1]

Problem

Areas within the San Luis Valley (SLV) in south-central Colorado have groundwater nitrate-nitrogen (NO_3-N) concentrations that exceed federal drinking water standards. Topography, climate, soils and agricultural practices contribute to the problem. Irrigated agriculture, including potatoes, small grains, vegetables, forage and oil crops are the main industry of the region encompassing over 147,000 hectares. The USDA-Natural Resource and Conservation Service has established the SLV Water Quality Demonstration Project to promote the use of Best Management Practices (BMP) to minimize agricultural non-point pollution of water resources in the valley. As calibration is proceeding, the USDA-Agricultural Research Service NLEAP (Nitrate Leaching and Economic Assessment Package) model is beginning to be used to evaluate various management practices in the area.

Approach

Demonstration sites on 18 cooperating farms utilizing current management practices have been established in the SLV. These sites were selected to reflect agricultural systems with high NO_3-N leaching potential and economic, ethnic and agronomic diversity. On-farm data and plant and soil-samples collection is in progress for NLEAP simulations of management practices and nitrate leaching potential. Cropping systems studied include small grains (4 fields Barley; 1 field Oats and 1 field Wheat), Potatoes (8 fields in 3 varieties) and Lettuce (1 field in 3 varieties). Fields are distributed across many course-textured soils, ranging from cobbly sandy loam to loamy sand.

Results

Data from NLEAP simulations suggests that for the farms studied, approximately 17,300 kg (19 tons) of NO_3-N was removed from the aquifer via irrigation using current management practices Nitrate-N leached below the bottom of the root-zone potato fields, was not significantly different than for small grain systems, even though N-fertilizer inputs for potatoes were 5 times greater than for barley. Moreover, measured residual soil nitrate in the crop root-zone, which is subject to leaching, was not significantly different between the potato and small grain cropping systems. However, the potential for nitrate leaching per unit of land area is approximately 3 times greater for lettuce compared to potatoes or small grains. These simulations will help identify cropping systems that are prone to NO_3-N leaching on the farms studied.

Future plans

NLEAP will be used to study various management systems in the SLV: 1) Evaluate crop varietal effects on nitrate movement, 2) Use of various crop rotations and fertilizer timing/amount to minimize nitrate leaching, 3) Evaluate organic/inorganic fertilizer management alternatives for potatoes, carrots and lettuce, and 4) Incorporation of farm economics into identified management practices.

[1] USDA-NRCS, San Luis Valley Water Quality Demonstration Project.

LIMITING NITROGEN LOSSES USING NITRIFICATION INHIBITORS AND CONTROL RELEASE UREA

Author(s) A.R. Mosier and J.A. Delgado; -Coinvestigators: J.R. Freney[1] and G. Keerthisinghe[1]

Problem

Efficient use of N fertilizers is minimized in many agricultural systems because of the loss of large amounts of the applied N through nitrate (NO_3) leaching, by ammonia volatilization or by denitrification. A key to limiting all of these loss processes is to maintain NO_3 N concentrations in the soil as low as possible throughout the year when crop demand is low. Since N fertilization is required to maintain crop production, N can be applied frequently through the cropping season, nitrification inhibitors can be used, or control release fertilizers can be applied to minimize NO_3 accumulation. Frequent N applications in most cropping systems adds cost and is impractical, nitrification inhibitors can be functional but most have serious limitations. Generally the easiest method of fertilizer application is at crop planting. Using control release fertilizers at planting or newly developed nitrification inhibitors are possible means of improving the efficiency of a single application of N at planting. Efforts to develop improved coating techniques for calcium carbide are still being pursued.

Approach

Field studies using ^{15}N were conducted in spring barley and winter wheat to test the effect of polyolefin coated urea and nitrification inhibitors on crop yield and N losses and in flooded rice to test the effect of coated calcium carbide, a nitrification inhibitor we are developing, on N losses.

Results

Field studies were conducted to compare N-use efficiency and effect on N_2O and CH_4 flux, of urea, urea plus the nitrification inhibitor dicyandiamide (DCD) and polyolefin coated urea (Meister-7)(POCU) in irrigated spring barley and winter wheat (Meister-15) grown in a clay soil in northeastern CO. Total recovery of N in plant and soil at harvest from POCU was 95% compared to 80 and 84% recovery from urea and urea + DCD, respectively for spring barley. POCU and DCD both decreased nitrate movement below the root zone. For winter wheat DCD and POCU decreased N_2O emissions by 150 and 200%, respectively. In flooded rice coated calcium carbide decreased denitrification losses of urea N by about 50%.

Future plans

Parts of the winter wheat study are still being analyzed for N and ^{15}N. A new POCU study was initiated in September, 1994 to determine the effect of POCU placement and type of POCU on winter wheat yield. Future work on coated calcium carbide as a nitrification inhibitor depends upon development of an improved encapsulation technique which reproducibly releases the required amount of acetylene at the needed time. We are working with Dr. Bernie Byrnes at the International Fertilizer and Development Corporation, Muscle Shoals, AL to attain funding for IFDC to work on the encapsulation problem and then to conduct field trials on the new product.

[1]CSIRO, Div. Plant Ind. Canberra, ACT Australia

BUILDING A NORTH AMERICAN TRACE GAS NETWORK

Author(s)

A.R. Mosier; -Coinvestigators: D.S. Ojima[1], E.A. Holland[2], J.A. Melillo[3] and G.P. Robertson[4]

Problem

Many trace gas research programs are being conducted in North America. Data is being collected in a wide variety of ecosystems that could be used to answer regional and global questions concerning trace gases. Currently much of the information is fragmented and is not readily accessible by the scientific community as a whole.

Approach

In September, 1992 a scientific and organizational planning workshop was held at Pingree Park, CO to develop a program to integrate sites across North America where fluxes of CO_2, CH_4 and N_2O and other trace gases are being made. Concomitantly the development and implementation of quantitative flux models at several geographic scales was planned. This Trace Gas Network (TRAGNET) is designed to fulfill the U.S. contribution to the world-wide program being established under the auspices of IGBP/IGAC. The project relates particularly to the IGBP/IGAC Activity 5.2 (TRAGEX 1992), which is specifically aimed at characterizing trace gas fluxes in the mid-latitudes.

Results

TRAGNET, however, will utilize data from both more northern and more southern locations as well. In September, 1994 the U.S. National Science Foundation provided funds to permit establishment of a TRAGNET activity. Under this program, TRAGNET will establish a database and model analyses to be used in determining general relationships of trace gas exchange across broad environmental gradients in climate, atmospheric deposition of N, and soils. The Network includes, as a core, many LTER sites and other long-term research sites where trace gases are being measured and locations where trace gas model development is being conducted. Establishment of models and data bases with which to use the models is being initiated at the Natural Resource Ecology Laboratory (NREL) at Colorado State University (CSU) as a task of TRAGNET. A.R. Mosier is chairman of the program steering committee and project coordinator.

Future plans

A system for archiving gas flux and ancillary data and gas flux models will be developed and implemented. Using these data and models trace gas fluxes from a variety of ecosystems will be prepared and related to global sources and sinks of the various trace gases.

[1]NREL, CSU; [2]NCAR, Boulder, CO; MBL, Woods Hole, MA; KBS, Hickory Corners, MI

SOIL-ATMOSPHERE EXCHANGE OF CH_4, N_2O AND CO_2: INFLUENCE OF N FERTILIZATION IN GRASSLANDS IN ALASKA, COLORADO AND PUERTO RICO

Author(s) A.R. Mosier, J.A. Delgado and R.F. Follett; -Coinvestigators: V. L. Cochran[1] and D.W. Valentine[2]

Problem

CH_4 and N_2O are atmospheric trace gases which, like CO_2, contribute to the global climate. According to the latest IPCC estimates CH_4 and N_2O will within the next half century equal or exceed CO_2 in global warming potential. Since approximately 70% of the fluxes of CH_4 and N_2O are mediated in the soil, it is soil process that will dictate future atmospheric loading of these gases. Grasslands are an important part of global terrestrial ecosystems, with savannas, tropical grasslands and temperate grasslands comprising about 20% of land area . Changes have occurred and are occurring in land use and management practices in grassland systems which have and will alter the biogeochemical nutrient cycles which impact the atmospheric concentrations of CH_4 and N_2O. Grasslands typically serve as a sink for atmospheric CH_4 and source for N_2O but until recently the impact of land use and management was unknown. Our studies were initiated to determine the influence of management practices on trace gas fluxes across a wide climatic gradient, using grassland sites in AK, CO and PR.

Approach

Weekly gas flux measurements, using closed chambers, were initiated in the CO shortgrass steppe on fertilized and unfertilized pastures in 1990 and on two grassland sites near Fairbanks, AK and three sites in western PR in 1992. The sites in AK and PR were established within grass fields that had been established for more than 10 and 25 years, respectively. A set of fertilized and unfertilized plots were established with fertilizer application annually in AK and quarterly in PR using practices normal for forage production at each site.

Results

Long term effects of land use change and N-fertilization are evident within the CO short grass steppe where both decreased uptake of atmospheric CH_4 by about 30%. In managed grasslands in both AK and western PR, no long-term N fertilization effects on CH_4 uptake were observed. CH_4 consumption rates averaged about 40 ug CH_4-C m^{-2} hr^{-1} in the native CO grassland compared to about 5 in PR and average summer consumption rates of 16 in AK. N_2O emissions are increased 2-3 times for over a decade from one application of N in the CO grassland while increased N_2O production is short-lived in both the subarctic and tropical grasslands. N_2O emissions averaged 1.9 and 2.1 ug N m^{-2} hr^{-1} in unfertilized sites and 6.1 and 3.4 from fertilized sites in AK and CO, respectively. The N_2O emissions from the unfertilized PR sites averaged about 17 ug N m^{-2} hr^{-1} and increased 2 to 3 times with fertilization.

Future plans

Data collection ended in 1994 in AK with the closure of the station and will end in September 1995 in PR. Long term data collection, through collaboration with LTER, will continue in CO. Many publications are to be written and data will be used in gas flux model development and validation. These data will be input into the TRAGNET system.

[1]USDA/ARS (formerly in Fairbanks now Sidney Montana; [2]NREL, CSU

SOIL-ATMOSPHERE EXCHANGE OF CH_4, N_2O AND CO_2: AGRICULTURAL SYSTEMS IN NORTHEASTERN COLORADO

Author(s) A.R. Mosier and J.A. Delgado

Problem

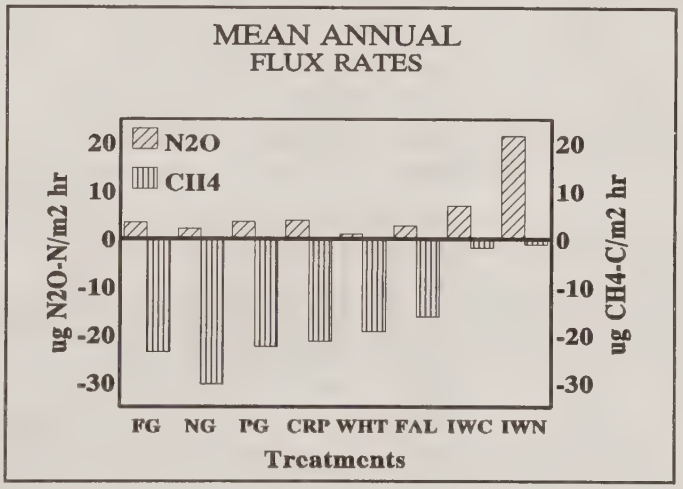
Since the fluxes of CH_4 and N_2O from the earth's surface to the atmosphere are primarily controlled by soil biogeochemical processes we assume that changes in N cycling in soils due to agricultural practices have influenced the increases in atmospheric N_2O and CH_4 during the past century and will help dictate future changes. The influence of agriculture and agricultural management practices on the fluxes of on N_2O emissions and CH_4 consumption in soils are not well known as little field flux data exists. We initiated a long term field flux measurement program to assess the soil-atmosphere exchange of trace gases in a variety of systems ranging from native grassland to irrigated crops.

Approach

The soil-atmosphere exchange of CH_4 and N_2O were measured using chambers that were adapted to the agricultural system being studied. Flux measurements were made daily to bimonthly year-round, depending upon the time of year and cropping situation. During the 1994 calendar year we measured fluxes in native grassland (NG), grassland that had been N fertilized from 1976 to 1989 (FG), grassland that was first plowed in 1992 (PG), wheat-fallow fields (one placed in the conservation reserve program in 1985 (CRP), one planted to wheat in September, 1993 (WHT), and one planted to wheat in September, 1994 (FAL)), and an irrigated wheat field (where no fertilizer was added (IWC) and another where 90 kg N ha^{-1} urea N was applied (IWN))

Results

We observed the following trends: (1) that in the NG there is a long-term effect of N addition and plowing on both N_2O emission and CH_4 uptake (N_2O emissions are increased 160% and CH_4 uptake decreased 25%); (2) in the CRP N_2O fluxes remain 170% higher and CH_4 uptake 30% lower than NG; (3) N_2O emissions were 50% lower from the WHT than from the NG or the FAL while CH_4 uptake rates averaged 35 and 44%, respectively; (4) N_2O emissions in IWC and IWN were 304 and 945% that of the NG while CH_4 uptake was 6 and 4% of the NG, respectively. Generally, as cropping intensity increases N_2O flux increases and CH_4 consumption decreases.



Future plans

Flux measurements will continue in selected systems. The data collected will be used in developing, validating and using gas flux models in regional gas flux estimates and will be provided for use by TRAGNET.

SOIL ATMOSPHERE EXCHANGE OF CH_4, N_2O AND CO_2: EFFECT OF SOIL TYPE AND N FERTILIZATION IN WESTERN PUERTO RICAN GRASSLANDS

Author(s) A.R. Mosier, J.A. Delgado and R.F. Follett

Problem

The conversion of native tropical systems into agricultural uses has been considered a major factor in the resent upsurge in increases in atmospheric N_2O. The systems that had been studied were generally those from recent conversion. Little is known about tropical systems that have been converted from forest to intensive agriculture which then were returned to relatively stable grasslands that are used for forage production. In PR this series of changes has occurred on a large portion of the arable land during the past two centuries over a variety of different soils. There is also little information available concerning the influence of soil type or N fertilization on CH_4 and N_2O flux in established, managed tropical grasslands.

Approach

Sets of fertilized and unamended plots were established on an Oxisol, a Ultisol and a Vertisol near Isabela, Mayaguez and Lajas, respectively, in western PR. Fertilization rates used were recommended for local forage production were used. Gas fluxes and various soil parameters were monitored weekly from each location from the autumn of 1992 until the present time.

Results

Mean annual CH_4 uptake rates were the same in 1993 and 1994 in the Ultisol and Vertisol and were not altered by N-fertilization. In the Oxisol, however, CH_4 uptake rates were appreciably lower in 1994 than in 1993 and were significantly decreased by N fertilization in 1994. Nitrous oxide emissions from the unfertilized Oxisol, Ultisol and Vertisol were not significantly different and ranged from 15.8 to 18.3 ug N m^{-2} hr^{-1} at all three sites. Fertilization increased N_2O emissions 2 to 2.5 times in the Oxisol and Ultisol both years and 3.7 and 7.4 times in 1993 and 1994. The data suggest that the effect of fertilizing on CH_4 oxidation is beginning to become evident in the Oxisol while longer term enhancement of N_2O emissions is appearing in the Vertisol.

Site	Year	Mean Annual CH_4 and N_2O Flux ---No N---		---+ N---	
		--- ug C or N m^{-2} hr^{-1} ---			
Isabela	1993	-4.3	17	-3.8	34
	1994	-2.7	18	-0.8	41
Mayaguez	1993	-2.7	18	-4.5	35
	1994	-3.3	17	-4.8	44
Lajas	1993	-7.9	16	-7.4	59
	1994	-6.3	16	-6.7	117

Future plans

Flux measurements will continue until September, 1995. When the data set is complete it will be analyzed and manuscripts prepared. The data will be used in our regional modeling effort and provided for TRAGNET.

SOIL-ATMOSPHERE EXCHANGE OF CH_4, N_2O AND CO_2: SUBALPINE FORESTS IN SOUTHEASTERN WYOMING

Author(s) A.R. Mosier; -Coinvestigators: R.A. Sommerfeld[1], R.C. Musselman[1] and J. Vermulen[2]

Problem

Since approximately 70% of the fluxes of CH_4 and N_2O are mediated in the soil, it is soil process that will dictate future atmospheric loading of these gases. Subalpine forests are an important part of global terrestrial ecosystems, comprising about 8% of land area and little information exists concerning trace gas production and consumption in the systems. Studies were initiated to quantify the soil-atmosphere exchange of CH_4, N_2O and CO_2 in two forest subalpine sites in southeastern WY.

Approach

Gas flux measurements using closed chambers were conducted weekly throughout the snow-free season during 1991-1993 at the USDA/Forest Service Glacier Lakes Ecosystem Experimental Site (GLEES)in the Snowy Range of the Medicine Bow mountains. Two forest sites were selected in Englemann spruce (*Picea englemanni*) at 3182 (site A) and 3286 (site B) m elevation. In addition to flux measurements a number of ancillary measurements to be used in interpretation and modeling were also taken at the time of each flux measurement.

Results

The mean seasonal flux rates for CO_2, N_2O and CH_4 for sites A and B were 90 and 97 mg C m^{-2} hr^{-1}, 1.6 and 1.0 ug N m^{-2} hr^{-1}, and -19.6 and -16.2 ug C m^{-2} hr^{-1}, respectively. Fluxes were not statistically different between sites for any of the gases. The mean seasonal gas fluxes in site A, measured in 1991 and 1992, were not statistically different in previous years from those measured in 1993. This WY subalpine forest is a small, and rather stable, source of N_2O. Extrapolating these N_2O emission rates to similar forests areas globally, approximately 12 X 10^6 km^2, the total N_2O-N flux is about 0.14 Tg yr^{-1}. For CH_4, extrapolating mean CH_4 flux rates, about -60 mg C m^{-2} yr^{-1}, to this type of forest globally indicates a flux of -0.7 Tg CH_4-C yr^{-1}. These studies clearly demonstrate that cold soils serve both as sources and sinks for N_2O and CH_4, respectively, and that soil water is the basic controller of CH_4 flux.

Future plans

There are no immediate plans for continuing gas flux measurements at these sites. Data analyses will completed during the coming year and manuscript preparation will follow. These data will be used in trace gas model testing and TRAGNET efforts.

[1]USDA/Forest Service, Fort Collins; [2]Department of Air Quality Wageningen Agricultural University, The Netherlands.

SOIL-ATMOSPHERE EXCHANGE OF CH_4, N_2O AND CO_2: IMPORTANCE OF YEAR-ROUND MEASUREMENTS

Author(s) A.R. Mosier; -Coinvestigators: R.A. Sommerfeld[1], D.W. Valentine[2], W.J. Parton[2], D.S. Schimel[3], and D.S. Ojima[2]

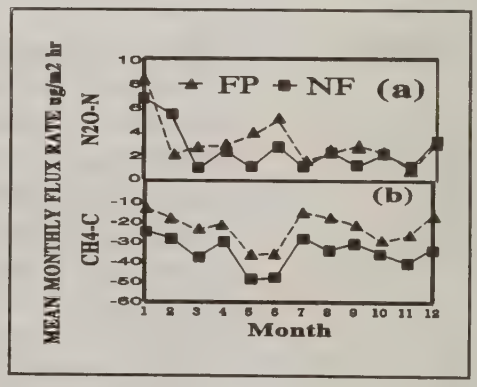
Problem

Most trace-gas exchange between the soil and the atmosphere stops when soil is snow covered or soil temperatures drop to about 0°C. Since soil temperatures are at this temperature or below for a large part of each year and snow can cover between 44 and 53% of the land area of the Northern Hemisphere for more than half the year in alpine and sub-alpine regions these parts of the year are not usually considered important in global budgets of CH_4, N_2O and CO_2.

Approach

In systems where soils are not typically snow covered, like the grasslands and cultivated fields of eastern CO and western NE, the soil-atmosphere exchange of CH_4, N_2O and CO_2 were measured year-round at 20-30 locations using closed chamber techniques. In sub-alpine systems gas fluxes were measured by measuring gas concentration gradients within the snow and calculating the fluxes using diffusion equations.

Results



In the subalpine systems soils beneath the snow pack emit CO_2 and N_2O and take up atmospheric CH_4 throughout the snow-covered period. Soil respiration under the snow represents oxidation of more than 25% of the estimated carbon fixed in the ecosystem during the growing season. About 30% of the annual CH_4 consumption and 32% of the N_2O emission in the sub-alpine system occurred during the snow-covered period. In the grasslands Nov.-Feb. fluxes of NO and N_2O comprise 10-50% of the annual mean flux. There are times during the winter when surface soils thaw and moisture content of the thawed surface is high when N_2O fluxes are at some sites the peak for the year. These data (two sites from the CO grasslands as examples shown in graph) clearly show that gas fluxes that are controlled by soil microbial processes cannot be assumed to be negligible even when soil temperatures are near zero. Fluxes of N_2O, CH_4 and CO_2 during the four months of Nov.-Feb. comprised 15-56% of these gas fluxes. Using the assumption that Nov.-Feb. CH_4 uptake rates were zero underestimate the mean annual CH_4 uptake rate by 25-30%.

Future plans

Continued collaboration with USDA/Forest Service personnel will continue in looking at seasonal fluxes of trace gases in sub-alpine systems. Other flux measurements at selected sites in the CO short-grass steppe will continue on a year-round basis. These data are being used in model development and in the TRAGNET efforts.

[1]USDA/Forest Service, Ft. Collins; [2]NREL, CSU; [3]NCAR, Boulder, CO.

SOIL-ATMOSPHERE EXCHANGE OF CH_4, N_2O AND CO_2: USING FIELD FLUX MEASUREMENTS FOR DEVELOPMENT OF PROCESS BASED-GAS-FLUX MODELS FOR CH_4 AND N_2O

Author(s)

AR. Mosier and J.A. Delgado; -Coinvestigators: D.W. Valentine[1], W.J. Parton[1], D.S. Schimel[2] and D.S. Ojima[1]

Problem

Since it is not possible to measure gas fluxes in all soils at all times it is necessary to develop simulation models which accurately describe trace gas fluxes from a wide variety of soils and climates. Such models are needed to assess regional fluxes and assess the impact of perturbations on these gas fluxes.

Approach

Using the information collected during the past four years, from a wide variety of research sites, we have developed a set of first generation, process based models which describe the oxidation of CH_4 and production of N_2O in the soil.

Results

A general model was developed to simulate N_2 and N_2O fluxes from nitrification and denitrification. N_2O flux from nitrification is a function of the soil water filled pore space (WFPS), soil temperature and the maximum nitrification rate (soil specific parameter). The effect of WFPS on nitrification is a function of soil texture with the optimum value for nitrification occurring at higher WFPS for fine textured soils. Total N_2 and N_2O gas fluxes from denitrification are a function of the soil NO_3 level, soil respiration rate at 0.6 WFPS (index of available soil C) and soil WFPS. The maximum N gas flux from denitrification is calculated as the minimum of the soil respiration and soil NO_3 functions and reduced by WFPS function. Denitrification rates decrease as WFPS decreases below 0.9, with the rate decreasing most rapidly in the fine textured soils. The ratio of N_2:N_2O gas fluxes from denitrification is a function of soil respiration rate, soil NO_3 level and soil WFPS. The highest N_2:N_2O ratios occur for soils with low soil NO_3 levels, and high values of soil respiration and WFPS. The model is used to relate field-measured fluxes to the processes which drive the fluxes.

The CH_4 uptake model is based on the observation that CH_4 uptake rates are limited by diffusion, and can thus be modeled based on Fick's first law of diffusion in which flux is proportional to the concentration gradient with respect to soil depth. Diffusion coefficients are estimated as functions of pressure, temperature, soil bulk density, texture and moisture. A factor relating soil N turnover to CH_4 uptake is also included.

Future plans

Further refinement of these models and linkage to the CENTURY model is planned. Once that phase is accomplished then the model package will be linked with GIS systems to develop regional flux models. A proposal was submitted to the National Science Foundation in December, 1994 to acquire funding to support these efforts.

[1]NREL, CSU; [2]NCAR, Boulder, CO.

IMPORTANCE OF AEROBIC SOIL CONSUMPTION OF CH_4 ON THE GLOBAL CH_4 BUDGET AND RELATIVE EFFECT ON THE GLOBAL WARMING POTENTIAL OF TRACE GASES IN THE SHORT GRASS STEPPE

Author(s) A.R. Mosier; -Coinvestigators: D.W. Valentine[1] and D.S. Ojima[1]

Problem

Considerations of global budgets of atmospheric methane have typically focused on production sources. Consumption of CH_4, other than through hydroxyl radical reaction in the atmosphere, has also been given little attention. These considerations were in spite of a few measurements which indicated that aerobic soils potentially served as sinks for atmospheric methane. Our research was initiated partially to determine the soil sink strength for atmospheric CH_4 in a large variety of ecosystems.

Approach

Long-term field campaigns for trace gas flux measurement were initiated two to four years ago in managed grasslands in AK and PR, in native and managed agricultural systems in CO, in subalpine forests and a managed grassland in WY and in a long term tillage experiment in western NE. Weekly or more frequent flux measurements were made at each site, AK and the WY grasslands excepted, year-round.

Results

These studies are providing information which are confirming that aerobic soils are an important sink for atmospheric CH_4. These and other studies around the globe led to a reassessment of the soil sink strength by the latest IPCC assessment which concluded that the total global soil sink for atmospheric CH_4 is about 40 Tg C yr^{-1}. The soil CH_4 sink appears to be intimately tied to soil nitrogen dynamics and is strongly inhibited by fertilization or cultivation in some systems. This sink is similar in magnitude to other much more intensively studied terms of the global CH_4 budget, including emissions from rice paddies and enteric fermentation, and the rate of increase in the atmospheric CH_4 pool. Although it is clear that aerobic soil consumption of CH_4 is an important part of the global budget, how does a land area like the CO short grass steppe for example, impact the net green house gas flux? The grasslands produce N_2O and are used for cattle grazing part of the year. The cattle produce CH_4 through enteric fermentation. Since the grasses fix CO_2 we assume a net balance between fixation and respiration. Based on CPER stocking rates, animal size and diet, cattle produce about 0.16 kg CH_4 day^{-1} cow^{-1}. A pasture stocked at the moderate rate of 20 animals for a 130 ha pasture and 130 stocking days emits about 420 kg of CH_4 yr^{-1}. The pasture produces about 40 kg of N_2O yr^{-1} and consumes about 610 kg^{-1} of CH_4 yr^{-1}. Using IPCC-1994 global warming potential factors for CH_4 and N_2O, calculations indicate that because of the soil CH_4 sink, the short grass steppe has a net global warming capacity of -1100, ie is a net sink for greenhouse gases.

Future plans

Long term studies at selected sites will continue. Data analyses and publication of the results of studies from the various sites will reinforce the concept that the aerobic soil sink is an important part of the global CH_4 budget which is influenced by agricultural management.

[1]NREL, CSU.

INFLUENCE OF TILLAGE IN A WHEAT-FALLOW SYSTEM IN SOUTHWESTERN NEBRASKA ON CH_4, N_2O AND CO_2 FLUX AS THEY RELATE TO N TURNOVER AND SOIL MOISTURE

Author(s) A.R. Mosier; -Coinvestigator: J.A. Doran[1]

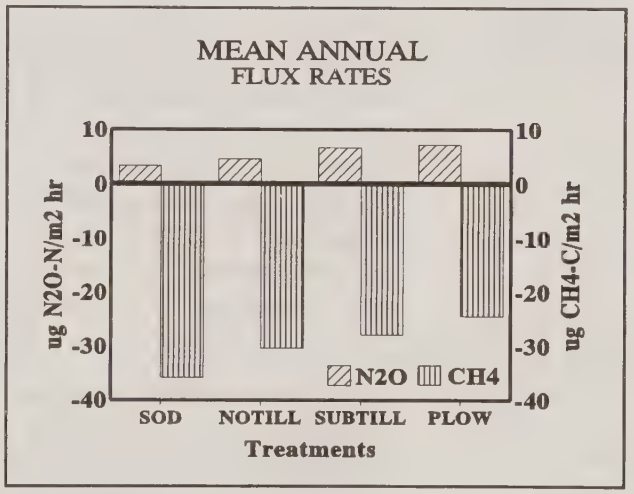
Problem

Methods of tillage have been shown to affect soil water storage, organic carbon and nitrogen distribution and the distribution and rates of a number of microbial processes in cropping systems. The influence of different long term tillage practices on the soil processes that affect the fluxes of important atmospheric trace gases, CH_4, N_2O and CO_2 in wheat-fallow systems are not know.

Approach

Field studies were initiated in March 1993 to permit measurement of trace gases and determination of a variety of soil parameters in the Sidney NE long-term tillage plots. Trace gas fluxes were measured weekly year-round and other soil parameters were measured periodically.

Results



The trend for the soil uptake of atmospheric CH_4 is sod>no till>subtill>plow and for N_2O efflux is plow=subtill>notill>sod. These measurements include times when plots were in fallow and times when wheat was planted. Typically the sod plots collected more moisture during the winter than did the wheat planted plots. The trends of soil moisture content in the upper 15 cm of the plots during the winter time were sod> notill> subtill=plow and were notill>subtill=plow>sod during the summer and autumn. Fluxes of CO_2 from the soil during seasons when the sod was brown were typically in the order sod>notill=subtill=plow. Increased tillage increased N_2O flux and decreased CH_4 uptake, likely through increased N turnover in the plowed soils. Moisture content of the plowed and subtill soils was typically lower than the notill and sod soils. If water were the only controller of the gas fluxes, CH_4 consumption should have been lower and N_2O emissions higher in the sod compared to the plow and subtill treatments.

Future plans

Trace gas flux measurements will continue until wheat planting time in September, 1995. Following that time all of the data will be analyzed and prepared for publication. The data will be used to determine if gas fluxes can be used as soil quality indicators, for gas flux model testing, and for use by TRAGNET.

[1]USDA/ARS Lincoln, NE.

NITROGEN BIOGEOCHEMISTRY AND N GAS EMISSIONS IN THE SHORTGRASS STEPPE

Author(s) A.R. Mosier; -Coinvestigators: M. Skoles[1], R. Martin, [2], D.S. Ojima[2], W.S. Parton[2] and O. Heinemeyer[3]

Problem

Recent studies in grasslands have found that gaseous N losses may be a keystone process regulating biogeochemistry of these ecosystems. Results from our studies at the CPER and data from other research indicate that rates of N gas loss from grasslands are similar to rates of atmospheric N inputs, suggesting that exports of N in gaseous form may well be the principal control on long-term grassland N balance and productivity. Along with its role in regulating primary productivity, the N cycle of terrestrial ecosystems interacts with atmospheric trace gas chemistry in important ways. Keys to understanding the dynamics and magnitudes of N gas fluxes are the relative and absolute of magnitude of processes and biological properties which regulate N turnover. These properties include the functional relationship between microbial biomass, N mineralization, immobilization, nitrification and denitrification.

Approach

From the 24 sites where trace gas studies have been or are being conducted in the CPER five were selected with differing textures, landscape positions and management. Within these sites simulated rainfall intensity was varied and the effect of various rainfall episodes on nitric oxide (NO) and N_2O, CH_4 and CO_2 fluxes were assessed. Concurrently, soils were analyzed for microbial biomass, net and gross N mineralization and immobilization estimates were made using ^{15}N dilution and other soil parameters. Dr. Mary Scholes, visiting scientist, and graduate student Robin Martin initiated the NO flux measurements and mineralization studies while the SIR measurements were made by Dr. Otto Heinemeyer.

Results

In the grassland sites simulated light and heavy rain storms resulted in large and rapid responses in NO (10-200 ug N m^{-2} hr^{-1}) and N_2O (1-50 ug N m^{-2} hr^{-1}) flux rates. Maximum rates were obtained in 30 minutes to 4 hours after wetting. NO flux rates were typically >10 times higher than N_2O flux rates in course textured soils but were lower in finer textured soils. The magnitude of the NO flux appeared to be related to the substrate availability and was well correlated with soil CO_2 fluxes. The duration of the flux was more closely controlled by the soil water filled pore space (WFPS). The NO flux rate peaked at approximately 35% WFPS for course textured soils but were relatively lower and showed less marked response to WFPS in finer textured soils. N_2O fluxes continued to increase with increased WFPS. NO and N_2O fluxes are highly correlated following moderate size wetting events but are not correlated following large rain events. Microbial biomass values for soils collected in early June show highest correlation with the anaerobic N mineralization and NO fluxes.

Future plans

Studies to further understand N biogeochemistry in the grassland as it relates to system productivity and NO, N_2O, CO_2 and CH_4 flux will continue.

[1]Univ. Witwatersrand, Johannesburg, South Africa; [2] NREL, CSU; [3]Federal Center for Agricultural Research, Braunschweig, Germany.

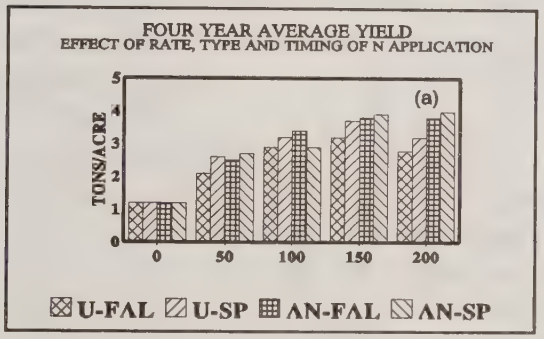
N MANAGEMENT IN AN IRRIGATED MOUNTAIN MEADOW

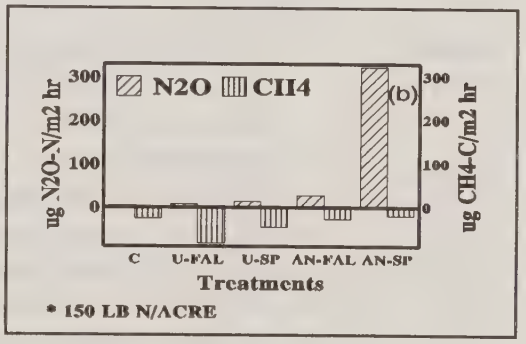
Author(s) A.R. Mosier, R.F. Follett and J.A. Delgado; -Coinvestigators: R.H. Follett[1] and D. Westfall[1]

Problem Mountain meadows play a vital role in livestock production in CO and WY. The average hay yield in these meadows is generally low (about 1.3 T/A). N fertilization studies were made from 1989 through 1993 to determine the effect of N source, timing and rate of N on forage yield at the CO State University Beef Improvement Center near Saratoga, WY. Neither the amount of fertilizer N recovered by the forage or effect of N on N_2O emissions were known in these systems.

Approach A set of plots were established where rates of N as either urea or ammonium nitrate of 0, 50, 100, 150, and 200 pounds/acre were applied in either spring or autumn. Hay production was measured annually. In 1992 and 1993 ^{15}N tracer studies were initiated to track the crop uptake and soil residue of the N applied. The flux of N_2O was measured weekly during the snow-free parts of the year.

Results Hay production was increased from an average of 1.2 T/A with no fertilizer to a maximum of 4.0 T/A with 200 lb/A of ammonium nitrate-N applied in the autumn. The





maximum financial return of $150-160/A was found with 150 lb/A of ammonium nitrate. Yields for U fertilization were slightly lower (Fig. A). Plant recovery of N is generally less than 40% with fall and 50% with spring application. Only spring application of ammonium nitrate significantly increased N_2O emissions. The timing of nitrate addition with irrigation, resulted in a loss of about 8% of the N applied as N_2O. The meadow served as a net source of CH_4 during the snow-free season (Fig. B).

Future Plans The study ended with the 1993 harvest. We have completed the laboratory part of the ^{15}N analyses but have not conducted an analysis of the data. Data analyses should be completed in 1995 and at least one manuscript prepared which describes the trace gas and ^{15}N study. The trace gas data will be used in our regional modeling effort and provided to TRAGNET.

[1]Dept. Soil and Crop Sciences, CSU.

EFFECT OF SOIL pH ON NITRIFICATION AND DENITRIFICATION AND THE FLUXES OF N_2O AND CH_4 IN AN OXISOL IN NORTHWESTERN PUERTO RICO

Author(s) A.R. Mosier and J.A. Delgado

Problem

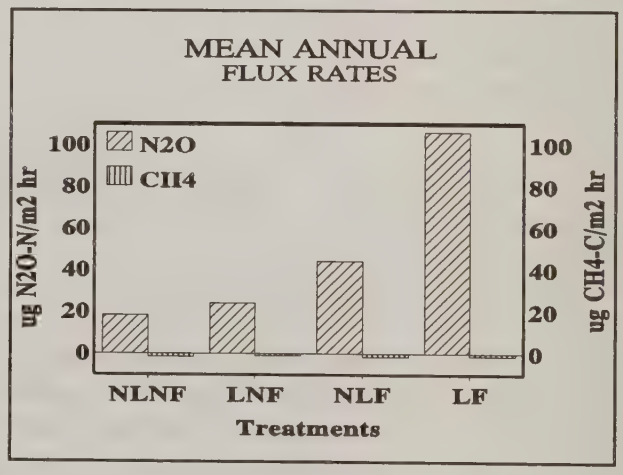
Many tropical soils are highly weathered and have a low pH. In these soils, N transformations such as nitrification are typically slower than in temperate soils. Management practices which strive to make these soils more amenable to growing crops, such as organic matter incorporation and liming, tend also to increase N turnover, nitrification , and denitrification and influence the ratio of N_2O to N_2 produced during denitrification. Studies were initiated to determine the effect of liming an acid Oxisol on N transformations and N_2O and CH_4 flux.

Approach

The soil at the Isabela research station is an Oxisol having a pH between 5.5 and 6.5. One field was artificially acidified in 1988 and the pH of this field remains at about 4.0. Within this acidified field a set of 24, 7 m X 7 m plots were established that incorporated lime (10 ton/ha) and fertilization. The six replicate plots include nonlimed, nonfertilized control (NLNF), lime (LNF), lime + fertilizer (LF) and no lime + fertilizer (NLF). Liming raised the pH to about 5.6. Fluxes of N_2O, CH_4 and CO_2 were monitored weekly.

Results

CH_4 flux rates were not affected by liming during the first three months of the study while N_2O emissions increased 1.4, 2.5 and 5.9 times in the LNF, NLF, and FL plots, respectively (Fig.). In laboratory studies with the limed and nonlimed soils, liming tripled nitrification rates and increased denitrification rates by almost 10 times. In these studies the ratio of N_2:N_2O increased from 1.0 in nonlimed soils to 3.6 in limed soils.



Future plans

Flux measurements and soil parameter measurements will continue until September, 1995. The data will then be analyzed and prepared for publication. These data will also be used in our regional model development and provided to TRAGNET.

^{15}N UPTAKE AND BALANCE IN A WHEAT-SORGHUM-FALLOW SEQUENCE UNDER NO-TILL IN THE SEMIARID GREAT PLAINS

Author(s) L.K. Porter, R.F. Follett - Co-investigator: A.D. Halvorson[1]

Problem

No-till cropping in the semiarid Great Plains has been made possible by the use of herbicides and improved machinery for planting into standing wheat stubble. The adoption of no-till in this region increases soil storage of precipitation and permits the adoption of a cropping sequence of winter wheat-grain sorghum-fallow. This cropping sequence requires additional N inputs to maintain sustainable yields. Information on plant recovery, and carryover at various rates of applied fertilizer nitrogen in this cropping sequence is needed.

Approach

A dryland field experiment was conducted at the Central Great Plains Research Station, Akron, Colorado. The field plot design consisted of three main plots (9.14 by 12.19m) with fertilizer N treatments of 0, 56, and 112 kg ha^{-1}, replicated four times. Each main plot was divided in to eight subplots (4.57 by 3.05m) and within the subplots were established ^{15}N microplots (2.29 by 1.83m). The microplots were fertilized at the same rate as the main plots. Some microplots received $K^{15}NO_3$ (10.37 atom %) to the first wheat crop, some received their first application of ^{15}N to the sorghum crop, some received the labeled ^{15}N to both crops, and in some cases labeled wheat residues were traded with plots where no ^{15}N had been applied. After the follow period an additional wheat crop, non-fertilized was used to measure ^{15}N carryover.

Results

The rate of fertilizer N had a highly significant effect on above-ground biomass yields, total N concentration, total-N and total- ^{15}N uptake of all the crops in the sequence. Nitrogen recovery of the applied ^{15}N was highest for this cropping sequence at the 56 kg ^{15}N ha^{-1} rate. Carryover of ^{15}N was highest for the 112 kg ^{15}N ha^{-1} rate and could contribute as much as 20% of the ^{15}N uptake of subsequent crops. The recovery of labeled fertilizer ^{15}N must be measured over a number of years as carryover affects not only the total recovery of ^{15}N but also the uptake of indigenous non-labeled soil N by subsequent crops and this was especially true at the 112 kg ^{15}N ha^{-1} fertilization rate. The 112 kg ^{15}N ha^{-1} rate caused a significant 'added N interaction' i.e. an increased uptake of indigenous soil N. Up to 25% of the ^{15}N in the wheat residues became available to subsequent crops over a 3 year span. At this rate at least 12 years would be required to release all the ^{15}N in the residues. A ^{15}N balance that reflected the ^{15}N contained in the standing stubble and the residue particulate materials on the soil surface was calculated by using the above-ground biomass minus ^{15}N mineralized from the residue and taken up by subsequent crops. Using this method ^{15}N losses at the 56 kg ^{15}N ha^{-1} fertilizer rate were < 10% of the ^{15}N applied. Losses at the 112 kg ^{15}N ha^{-1} fertilizer rate were generally at least twice those of the lower ^{15}N rate. At the end of the wheat-sorghum-fallow-wheat sequence 25-30% of the labeled ^{15}N remained in the 122cm soil profile.

Future plans

Measure carryover ^{15}N in an additional wheat crop.

[1] L.D. at the Northern Great Plains Research Laboratory, Mandan, ND

N_2 FIXATION BY CELLULOLYTIC MICROORGANIMS

Author(s) P. Scharf and L. K. Porter

Problem

Cellulose is the most abundant plant constituent in nature with an annual production of about $7.5*10^{10}$ tons. Cellulose products make up more than half of the materials entering U.S. municipal landfills and it is projected that the amount of cellulosic wastes to be disposed of will rise to 10^8 tons/year. It is estimated that landfill tipping fees may soon exceed $100/ton. Many agricultural and food processing wastes are primarily cellulose. Burning has been the traditional way to dispose of unwanted plant residues that could inhibit the growth of the subsequent crop, but this practice is being curtailed by law in many locations. Cellulose residues and cellulose products (largely paper) contain little or no N and are difficult to decompose. No organism higher than the fungi possess the enzymes necessary for degradation. Composting cellulose wastes may be a viable option, especially if microorganisms can be found that use the energy of the cellulose wastes to fix dinitrogen. Such organisms could potentially speed the decomposition process and increase the N content of the final product. Such nitrogen enriched product could potentially be used for mulch/fertilizer or as an animal feed.

Approach

The main thrust of the project is to measure N gain and mass loss in microbial cultures sampled from a wide range of natural locations and composting facilities. The cultures will be grown on N-limiting cellulose medium under oxygen levels ranging from atmospheric to anaerobic at 30 and 50°C. The cultures found to give the greatest N gains will be further characterized with regard to their N_2-fixing abilities using acetylene reduction and $^{15}N_2$ techniques.

Results

An economical system for establishing and maintaining microbial cultures at various oxygen levels has been designed and built using modified pressure cookers. A protocol for screening microorganism for their cellulose degradation/N_2-fixing capabilities under a range of O_2 conditions has been outlined. An experiment to choose the type of cellulose medium to use in the screening process has been completed. Experiments using this medium have shown that undefined mixed cultures are much more active in both processes than are pure cultures screened for the ability to grow on N-deficient cellulose media. These mixed cultures from a range of environmental sources are capable of reducing the C:N ratio of the cellulose cultures from 800:1 to 30:1 in 5 weeks. When linked the cellulose degradation and N_2-fixing processes occur most rapidly between with O_2 levels between 2 and 6%. A ^{15}N dilution field experiment set in Louisiana using ^{15}N-enriched soil with and without cellulose is being used to determine the effect of cellulose addition on non-symbiotic N_2 fixation in soil.

Future plans

Screen cultures to determine mass loss and N gain at 50°C. Analyze the isotope dilution experiment from Louisiana. Characterize the best cultures for their ability to fix N_2 with acetylene reduction and $^{15}N_2$. Test the best cultures for usefulness in operating municipal cellulose-composting facility.

SOIL-PLANT-NUTRIENT RESEARCH UNIT

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SUGARBEET RESEARCH UNIT

Earl G. Ruppel, Research Leader
Crops Research Laboratory
1701 Center Avenue
Fort Collins, CO 80526
TEL: (970) 498-4204
FAX: (970) 482-2909

FTS2000: a03rlcrl@attmail.com
INTERNET: eruppel@lamar.colostate.edu

MISSION STATEMENT

Utilize distinctive site environmental and disease-free characteristics and specifically developed team expertise to: develop new knowledge and adapt biotechnologies to modify host-pathogen relations that affect disease resistance, pathogenesis, and epidemiology in sugarbeet and other plant species pertinent to sugarbeet cultivation; discover new information and techniques to identify and produce genotypes exhibiting superior disease and stress tolerance and agronomic qualities; and provide new knowledge that improves production efficiency and biochemical processing characteristics of sugarbeet.

TECHNOLOGY TRANSFER - 1994

Sugarbeet Research Unit

1. Unit scientists and technicians have conducted numerous tours of their research facilities in the laboratory and field plots; visitors included elementary, high school, and university students, and scientists and administrators from universities and the beet sugar industry.

2. Research reports were written by Unit scientists for inclusion in a compilation of reports printed by the Beet Sugar Development Foundation (BSDF) and distributed to all seed and sugar companies and U.S. sugarbeet researchers. These and other reports were included in the 1993 annual report of the NRRC, which was distributed to over 200 researchers and research administrators.

3. Earl Ruppel presented the Unit's past and current research to the Board of Directors of the BSDF in Portland, OR, indicating proposed future sugarbeet research to be conducted by Unit scientists.

4. Susan Martin reviewed procedures and provided information on sucrose analysis methods to researchers at Ferry-Morse Seed Company, Modesto, CA. Dr. Martin also worked with the Director of Research for the Seedex Company, a sugarbeet seed producer, to solve sucrose analytical problems at the company's research lab.

5. Susan Martin and Lee Panella, at the invitation of the Western Sugar Company and three state sugarbeet growers' associations, consulted with processing staff on sampling techniques for sucrose analysis. The Unit scientists statistically evaluated company data, recommended additional testing, and analyzed and interpreted additional data.

6. Susan Martin and Lee Panella participated in a 3-state meeting of research and extension personnel working with sugarbeets or dry beans. The group discussed opportunities for regional research and extension activities, and ways to include sugarbeet and bean growers' input in establishing regional priorities. Ideas discussed included organizing a regional educational meeting for bean and/or beet producers, producing regionalized educational products and publications, maintaining a regional calendar of events pertaining to these crops, and establishing a pool of resources that could be allocated competitively to regional projects.

7. Lee Panella discussed breeding objectives, field experiments, and program objectives with Austrian scientists and sugarbeet growers visiting Hilleshög Mono-hy Sugarbeet Seed Company in Longmont, CO. He also presented a lecture in the course "Use of Transgenic Plants in Agriculture" offered jointly by the CSU Department of Plant Pathology & Weed Science and the Department of Entomology.

FUNGI IN OR ON SUGARBEET SEED: THEIR PATHOGENICITY AND EFFECT ON STAND ESTABLISHMENT

Author(s) E. G. Ruppel

Problem

Sugarbeet seedling death frequently occurs in seed germination tests or when growers plant the crop in the field. Many different fungi have been isolated from sugarbeet seed and diseased seedlings, but their association with seedling disease often has not been determined.

Approach

Different growth media are used to isolate fungi from six seed lots produced in Oregon, local field isolation plots, and in our greenhouse isolation cages; isolations are made from seed that have been surface-disinfested and from raw seed. The fungi are maintained in single, pure culture and their identity determined. Random isolates are retained for future tests to determine their ability to cause seedling death. Seed fungicides registered for use on sugarbeet seed will be tested for their toxicity to any new fungal pathogens detected in this study.

Results

A total of 269 isolates have been identified from three of the six seed lots, representing 18 different fungal genera. The majority of isolates (62-70%) are not known to cause disease in sugarbeet. Twenty-six random isolates have been retained in pure culture and will be tested for their ability to cause seedling disease.

Future plans

Isolations will be made from three additional seed lots. Those isolates kept for testing their ability to cause seedling death will be tested in pot culture of sugarbeet. Seed fungicides registered for use on sugarbeet will be tested for ability to control any disease-causing isolates identified in this study.

FIELD EVALUATIONS OF SUGARBEET FOR LEAF SPOT RESISTANCE

Author(s) E. G. Ruppel and P. A. Noble

Problem

Sugarbeet leaf spot, caused by a fungus (*Cercospora beticola*) is a disease of worldwide importance. Control with fungicides is expensive and not environmentally sound. Genetic resistance is the most economical and logical means of reducing losses from this disease, and our laboratory has been instrumental in developing resistant sugarbeets for over 60 years. Also, our knowledge in developing the disease in the field for the purpose of testing sugarbeet lines is used by other sugarbeet breeders for testing their hybrids produced with our resistant materials.

Approach

Cercospora leaf spot develops under warm, humid conditions. To produce the disease, we spray the fungus on the leaves, then create the necessary humid conditions by repeated overhead sprinkler irrigations. As leaf spots develop, the fungus produces reproductive spores that are then spread by splashing irrigation water. Disease is evaluated in late August - early September by assessing a value of 1 thru 9 in increasing disease severity. The final disease level of any sugarbeet line is the average of three replications. Each year, four or five sugar or beet seed companies submit more than 200 lines for evaluation in replicated tests in our field nursery.

Results

Our annual field leaf spot nursery provides an objective means for sugarbeet breeders to have their lines and varieties evaluated for resistance to the leaf spot fungus. The nursery also allows us to test lines that we are developing for increased resistance to the disease. Without exception, our leaf-spot resistant line used as a control in our nurseries has less disease than 95% or more of the commercial lines. Using our resistant materials in developing their hybrids, sugarbeet breeders have made steady improvements in leaf spot resistance in their commercial varieties.

Future plans

We will continue to provide this service.

FIELD EVALUATIONS OF SUGARBEET FOR RESISTANCE TO ROOT ROT

Author(s) E. G. Ruppel, L. Panella, and P. A. Noble

Problem

Root rot of mature sugarbeets, caused by the fungus *Rhizoctonia solani*, results in serious yield losses in most production areas. Partially rotted roots that end up in the sugar factory create additional problems in sugar extraction. No chemicals are registered for controlling this disease; cultural control measures are only partially effective. We have found and developed the only source of genetic resistance to this fungus, which company breeders incorporate into their lines. However, most company breeders do not have the facilities or expertise for establishing disease field nurseries for testing their lines or varieties. Also, other root diseases in many company areas make assessment of Rhizoctonia resistance difficult if not impossible. Our fields are relatively free of other disease problems.

Approach

We grow the fungus on moist barley grain, which ultimately is air-dried, then ground in a mill to a fine consistency. This inoculum is applied to the crowns of 2-month-old sugarbeets in the field; overhead sprinkler irrigation for 4 days is used to wet and activate the fungus. Evaluations for resistance are made in early September, when the roots are harvested and rated for rot on an increasing disease scale of 0 to 7. Approximately six to seven sugar or seed companies submit about 175 lines for testing annually.

Results

Rhizoctonia root rot continues to increase in many production areas.

Future plans

We will continue to improve genetic resistance in our lines and to evaluate breeders' lines in our disease nursery.

GERMPLASM DEVELOPMENTS FOR RESISTANCE TO SUGARBEET DISEASES

Author(s) L. Panella, E. G. Ruppel, and R. J. Hecker (retired)

Problem

Rhizoctonia solani and *Cercospora beticola* are two fungi that may produce a severe reduction of yield in many sugarbeet production areas. Cultural control measures are not adequate by themselves, and often no chemicals are registered for control of these diseases, or chemical control is expensive or environmentally unsafe. Increased levels of genetic resistance are needed to minimize growers' losses from these diseases.

Approach

Genetic information developed previously in our research was used to execute additional cycles of pathogen inoculation, plant selection, and recombination among germplasms that we have in our cyclic improvement program. Germplasms in various stages of improvement were evaluated for resistance in inoculated field tests. Results of these tests were the basis of decisions about specific germplasm, i.e., retain, shelve, discard, recombine, release, register, etc. Germplasms likely to be useful for variety improvement were identified and released for use by other sugarbeet breeders.

Results

Lines developed under the breeding program of Dr. R. J. Hecker are still being evaluated in the field. Nineteen lines were field-tested this summer for resistance to *R. solani*, *C. beticola*, and the curly top virus. Seed was increased from three lines, FC709(4X), FC710(4X), and FC712(4X), that were converted to tetraploidy (4X) with colchicine treatment. They are lines that previously were released from the Fort Collins program as diploids (2X), with high resistance to Rhizoctonia root rot and good combining ability. A few more lines developed in Dr. Hecker's program were increased in isolation plots this summer.

Future plans

Lines showing outstanding performance in 1994 field trials will be released in 1995. The tetraploids, along with a few other lines increased this summer, will be tested in the summer of 1995 and the best of these lines subsequently released.

BASE POPULATIONS TO DEVELOP MULTIPLE DISEASE RESISTANCE IN SUGARBEET

Author(s) L. Panella

Problem

In a hybrid crop like sugarbeets, it is preferable that all of the parents contain some level of resistance to diseases prevalent in the area in which the hybrid is to be grown. Multiple disease resistance is a difficult goal in a crop improvement program, especially when working with an outcrossing species. In alternating generations of selection, some of the progress made in resistance to one disease is lost while selecting for resistance to other diseases.

Approach

One means of solving the problem of selecting for multiple disease resistance is the use of progeny testing. By testing the progeny of individual mother roots, plants with multiple disease resistance can be identified and used as parents of the next generation. The most efficient use of progeny testing is when the genotype of both parents is known, and the easiest way to do this is through self-pollination. Material from the USDA-ARS breeding program at Salinas, CA, has been crossed with some of the Fort Collins lines most resistant to *Rhizoctoni solani* and *Cercospora beticola*. The Salinas material contains a broad spectrum of resistance to diseases of importance in California as well as other sugarbeet production areas (including rhizomania, powdery mildew, virus yellows, and curly top virus).

Results

Two source populations were grown in the 1994 steckling field. One is a monogerm population segregating for Rhizoctonia root rot and other disease resistances, self-fertility, and genetic male sterility; the other is a monogerm population segregating for Cercospora leaf spot and other disease resistances, self-fertility, and genetic male sterility. A multigerm source population segregating for Cercospora leaf spot resistance, other disease resistances, and self-fertility is being grown in the greenhouse.

Future plans

The monogerm populations from the steckling field (F_1 populations) will be intra-crossed ('selfed') in the greenhouse this winter. The multigerm Cercospora leaf spot population will be crossed to 4918aa from the USDA-ARS program in Salinas (further selection of C918) to introduce genetic male sterility and tolerance to the curly top virus. A multigerm Rhizoctonia root rot resistant population (F_1) will be planted in the steckling field in 1995. These populations, together with the materials from Dr. Hecker's program and Dr. Smith's Cercospora breeding program in Fargo, will form the basis of two breeding projects, each containing a strong laboratory component. One will focus on understanding the genetics of the *R. solani*-sugarbeet interaction and producing multiple disease resistance in sugarbeets. The other will focus on understanding the genetics of the *C. beticola*-sugarbeet interaction, and producing strong and stable host plant resistance.

CERCOSPORA LEAF SPOT RESEARCH AND BREEDING FOR CERCOSPORA/CURLY TOP RESISTANCE

Author(s) L. Panella and G. A. Smith[1]

Problem

Cercospora resistance is especially relevant in view of the following facts: (1) If the level of resistance seen in the most Cercospora-resistant lines were present in commercial hybrids (along with good sugar and seed yield), chemical sprays would not be necessary or the allowable amounts used might be reduced; (2) The efficacy of the chemical may be diminished by pathogen resistance (which already has been reported). From these facts, we can conclude that genetic resistance to *Cercospora beticola* will become increasingly more important.

The objectives of this program are: 1) The development of high Cercospora/curly top-resistant germplasm for release to the sugar industry. Lines will include monogerm CMS and O-type lines and multigerm pollinators. 2) To achieve number (1), coordination of breeding effort will continue between the Fort Collins and Fargo labs. Eventually, the germplasm enhancement program will be directed from Fort Collins.

Approach

A cross among a highly Cercospora-resistant line (FC607) , a smooth root line from the ARS Sugarbeet Research Unit in East Lansing (SR87), and high quality commercial hybrids developed by the defunct Great Western program (MonoHy A4, MonoHy T6, and MonoHy T7), is being made in the greenhouse at Fort Collins. This will lead to a population of pollinators highly resistant to *Cercospora*, with good agronomic traits. Individual mother roots will be grown in Masonville, taking advantage of pseudo self-fertility, and the selfed seed used to progeny test for sucrose, Cercospora resistance, and curly top resistance .

Results

Twenty advanced breeding lines or Cercospora-resistant germplasms were evaluated at the ARS leaf spot nursery at Ft. Collins. These lines are part of the resistant germplasm development effort at Fargo and Fort Collins. Currently flowering in the greenhouse is the group of parents described above. Hypocotyl color is being used as a marker to distinguish the hybrids.

Future plans

The seed will be harvested from the female (FC607) plants. Seedlings with red hypocotyl color will be established in the 1995 steckling field at Fort Collins. These will be planted in Masonville the following year and self-pollinated. Selfed seed from individual mother roots will be progeny tested. Remnant seed from the best-performing mother roots will be inter-crossed and the cycle repeated to produce populations of Cercospora resistant multigerm pollinators.

[1] USDA-ARS Geneticist and Research Leader, Northern Crop Science Lab.

INCREASE OF *BETA* PLANT INTRODUCTIONS AT FORT COLLINS

Author(s) L. Panella, P. Lundeen[1], and P. K. Bretting[1]

Problem

Historically, seed from the USDA-National-Plant-Germplasm-System *Beta* collection has been increased in Logan, UT, because of the favorable climate and the presence of a former ARS employee who supervised seed production. In recent years, that employee has retired and seed production has suffered. Additionally, the active *Beta* collection is being moved to Pullman from Ames. Currently, the Pullman Plant Introduction Station is testing the feasibility of increasing *Beta* introductions at a Pullman and a Snake River site. We wanted also to look at the feasibility of increasing *Beta* accessions in Fort Collins.

Approach

Seed from 10 accessions was received from the Plant Introduction Station at Ames, Iowa. These were similar to the accessions being tested at Pullman and Snake River. Seed from each of these accessions was split in half. One lot was planted in the steckling field used for breeding purposes at Fort Collins, and the other lot was planted in small plots, which could be tented over for controlled pollination in the 1995 field season.

Results

Two of the accessions in the steckling field bolted and flowered leaving the roots dead. They were not harvested. Although many of the other accessions bolted, most did not flower in their first season in the field. Roots were harvested on September 23 and placed in the Sugarbeet Research Unit's induction room. Symptoms of the curly top virus infection were observed on the foliage of many of these plants before harvest.

Seed also was planted north of the steckling field in small plots (3 ft^2), which can be tented over this coming field season. A heavy rain immediately after planting caused severe crusting of the soil, impeding seedling emergence. A serious bindweed infestation also adversely effected plant growth, and stands were poor. Surviving plants were mulched after the first killing frost. The mulch was a mixture of bark and hay, covered with chicken wire to keep the mulch in place during the strong winds common to the Fort Collins area.

Future plans

Roots harvested from the steckling field will be planted either in small groups and caged or in isolation plots. Survival of the roots and amount of seed produced will be quantified. Survival of those plants left to over-winter will be quantified. Any surviving plants will be caged and left to produce seed, and the amount of seed will be quantified. Results will be presented to the Pullman Plant Introduction Station, and a decision whether to investigate this question further will be made.

[1]USDA-ARS NCR; Plant Introduction Station; Iowa State University; Ames Iowa 50011.

THE EFFECT OF FOLIAR METHANOL APPLICATION ON SUGARBEET YIELD

Author(s) L. Panella, S. S. Martin and John N. Nishio[1]

Problem

Recently, researchers reported increased biomass production in agronomic and horticultural plants with foliar applications of methanol. Additionally, increased water-use efficiency was reported in some crops when methanol was sprayed during times of water stress. An increase in the aboveground biomass of sugarbeet may lead to increased production of sucrose or an increased rate of physiological development in the beet root. Another benefit would be a decrease in the amount of irrigation water needed to produce the beet crop.

Approach

In the field, three sugarbeet cultivars received three methanol treatments: 1) no spray; 2) sprayed with a solution of 50% methanol plus a spreader; and 3) sprayed with a solution of 50% methanol, nitrogen, and a spreader. Half the plots were well watered and half water stressed. One hundred eight plots (4 rows x 20 ft.) were sampled for root weight and percent sucrose; sucrose yield was calculated (weight X % sucrose). Twice during the season, photosynthesis was measured on a subset of the field plots. All data were analyzed statistically.

Results

Gas exchange measurements showed an increase in photosynthesis for those water-stressed plots sprayed with methanol. Methanol treatments caused statistically significant decreases in weight, sucrose, and sucrose yield (Table 1). A stimulation of photosynthesis normally results in increased biomass. For this to be beneficial in sugarbeet, the increase must occur in root weight or root sucrose percent, and an increase in one must occur without a compensatory decrease in the other. Although short-term increases in photosynthesis were measured in methanol-treated plants, both root weight and root sucrose decreased under methanol treatment. Possibly, increased photosynthesis resulted in increased aboveground growth at the expense of root growth and root sucrose storage. This effect often is seen when sugarbeet growth is stimulated by application of fertilizer late in the season.

Table 1

DIFFERENCES OF YIELD PARAMETERS
Averaged over block, irrigation, and variety

	Weight	Sucrose	Sucrose Yld.
Control	17.6 a	14.0 a	2.5 a
Methanol	16.9 b	13.7 ab	2.3 b
Meth+MSG	16.0 c	13.3 b	2.2 c

Means with the same letter (within parameter) are not significantly different (p=0.05)

Future plans

No further field trials are planned until a better understanding of the physiology and biochemistry of this phenomenon is achieved.

[1]Dr. J.N. Nishio is in the Department of Botany at the University of Wyoming.

GENETIC VARIATION AND PATHOGENICITY IN *RHIZOCTONIA SOLANI*

Author(s) L. Panella and M. K. Hjort[1]

Problem

Currently, it is possible to tell if an isolate of *R. solani* will attack sugarbeets only through a greenhouse test, which may take 12 to 16 weeks. Although there has been recent work done on genetic relationships among isolates (the "family tree") of this pathogen, relationships among isolates have not been well correlated with the plants that the fungus attacks. It is probable that isolates of this fungus in different genetic groups, interact differently when they attack the sugarbeet plant.

R. solani is divided into anastomosis groups (AGs) based on the ability of the hyphae to fuse and exchange genetic material, or, more recently, into intraspecific groups (ISGs) based on genetic molecular markers. Isolates of *R. solani* from AG-4 cause seedling death in sugarbeet, and isolates from AG-2-2 cause root and crown rot in mature beets.

Approach

We used the polymerase chain reaction (PCR) to amplify the DNA of *R. solani* in order to create molecular markers. Restriction enzymes, which cut this DNA into pieces, were used to make more molecular markers. These markers identified ISGs within AG-2-2. Isozyme markers (another class of genetic markers) are also being used to further discriminate ISGs. The *R. solani* isolates then will be tested for their ability to attack the sugarbeet plant. The genetic information from the markers will be correlated with the disease data from greenhouse tests to see if all the isolates which attack sugarbeet belong to the same evolutionary group(s). The sugarbeet-attacking group(s) will be identified with genetic markers.

Results

Currently, DNA from 95 isolates of *R. solani* has been analyzed. Some genetic molecular markers have been detected. There were also, in some cases, initial differences in the size of the length of DNA amplified, which varied from approximately 700 to 750 base pairs. The DNA was separated on agarose gels, visualized with ethidium bromide, and photographed. The enlarged photographs were used to estimate the fragment sizes, by comparison with fragments of known size.

Future plans

More enzymes will be used as needed to discriminate among the various ISGs in the different anastomosis groups. Greenhouse tests will be used to determine which isolates of *R. solani* attack sugarbeet. These data will be correlated with the genetic information. We will use this information to develop a quick test to determine if an isolate of Rhizoctonia will attack sugarbeet plants. Information on the relationships among isolates which attack sugarbeets should give us a deeper understanding of the interaction of the fungus and the plant which will help us to produce sugarbeets with stronger resistance to this fungus.

[1]Temporary faculty, Colorado State University, Department of Physiology

DEVELOPMENT OF MOLECULAR AND BIOCHEMICAL MARKERS FOR USE IN SUGARBEET BREEDING AND GENETICS

Author(s) L. Panella

Problem

Genetic markers are important tools that have long been used by plant breeders in the improvement of sugarbeet germplasm. One class of genetic marker, called a morphological marker, is caused by mutations that produce changes in the plant's appearance (e.g., red vs. green hypocotyls or leaves). Unfortunately, there are a limited number of morphological markers in any one sugarbeet plant or cultivar. More genetic markers would allow us to better understand and analyze genetic traits in sugarbeet hybrids and populations. Biochemical and molecular markers are types of genetic markers that are much more frequently present and often have no noticeable effects on plant vigor. These types of genetic markers can be very useful to breeders and geneticists.

Approach

Biochemical markers are a class of genetic markers that include enzymes produced by living organisms. These are often called isozymes. Molecular markers allow us to compare the DNA of one organism to that of another. We can use these markers to "fingerprint" plants and fungi, to make genetic maps, or to measure the genetic relatedness of organisms (construct "family trees").

Results

We are developing a data base of isozymes that are useful for working with *Rhizoctonia solani* (some isolates of which may cause root and crown rot in sugarbeet) and then using those isozymes to help understand the genetic relationships among isolates of this fungus that attack sugarbeet. Isozymes are also being used in sugarbeet genetic studies and our sugarbeet improvement program. Molecular markers created using the polymerase chain reaction have helped to define the relationships among the pathogenic isolates of *Rhizoctonia*. Another kind of sugarbeet molecular marker (RFLP probes) has been received from Dr. C. Jung's group at the Christian-Albrects-University in Kiel, Germany.

Future plans

We will continue to use these markers to study the interrelationships of the sugarbeet plant and its pathogens in order to develop techniques leading to the more efficient development and release of improved sugarbeet germplasm. These markers will also provide us with the tools to better understand and exploit the wild relatives of sugarbeet, which contain a reservoir of useful genes.

MODE OF ACTION OF TRAP CROPS FOR MANAGEMENT OF THE SUGARBEET CYST NEMATODE

Author(s) S. S. Martin, A. W. Lenssen[1], J. M. Thomas II, and L. Panella

Problem

The sugarbeet cyst nematode (SBCN), *Heterodera schachtii*, is an important sugarbeet pest that also attacks some other plants. At present SBCN is controlled by chemical application to soils or by long, multi-year rotations. Some cultivars of oil radish or yellow mustard resemble sugarbeet in causing "hatching" of SBCN cysts, attracting the juvenile nematodes, and allowing their establishment within the root, but then interrupt their reproduction, thus reducing soil populations of nematode cysts and the severity of disease when the soil is again planted to sugarbeet. We are trying to understand how these nematode "trap crops" disrupt the SBCN life cycle, so that better trap crops can be developed.

Approach

Glucosinolates (GSLs) are a class of special chemicals present in all members of the mustard plant family (to which radish and mustard belong). We investigated whether GSL composition or total quantity might differ between radish or mustard cultivars that are fully susceptible to SBCN (allow typical reproduction), and those that interrupt normal SBCN reproduction. We made a quantitative study of GSLs in roots and shoots of these cultivars, taking samples of greenhouse-grown plants at five stages: (1) Leaf production (5 true leaves); (2) Stem extension (15 cm stem); (3) Flower initiation (green flower buds visible); (4) Flowering (first flower fully expanded); and (5) Pod development (first pods with full-size seeds). Samples were cleaned, quick-frozen, freeze-dried, ground to a powder, and subsamples were extracted for analysis by HPLC (high performance liquid chromatography).

Results

Gucosinolate composition changed quantitatively and qualitatively through plant development. However, no qualitative or quantitative differences could be identified between radish or mustard cultivars that function as SBCN trap crops *versus* other cultivars that are fully susceptible and allow successful nematode reproduction. GSLs are contained in specialized cells, whereas our analyses were of whole-organ samples. Thus, we cannot rule out the possibility that localization of the GSL cells is important in determining nematode reproductive success.

Future plans

W are continuing to collect, identify, and purify GSLs, which we plan to use in bioassays of their effects on nematode hatching, attraction, or reproduction. We have been unsuccessful in attempts to hire a postdoctoral nematologist with skill in working with these organisms, so we have decided to obtain training for a person already in our research group. We also plan to begin tests of some other possible determinants of SBCN reproductive success, such as examining chemicals newly synthesized after root infection.

[1]Formerly, postdoctoral Research Associate, Sugarbeet Research Unit; currently, Department of Entomology, Montana State University.

EFFECT OF BREI SAW SPEED ON SUCROSE ANALYSIS OF SUGARBEETS

Author(s) S. S. Martin and L. Panella

Problem

Sugarbeet growers contract to deliver their crop to a processing company, and are paid for the sucrose ("sugar") in their beets, as measured at delivery. The "ideal" method for sampling for sucrose analysis is considered to be use of a single rasping blade, with each beet of a sample held in a carrier that passes the beet longitudinally over the rasp. This slow, labor-intensive method, however, is impractical for factory use. Instead, samples (typically 6-10 beets) taken from each truckload are dumped as a group onto a rapidly-rotating, multi-blade saw to prepare a fine, moist "brei," which is extracted and analyzed by polarimetry to determine sucrose content. Preliminary comparisons of rasp vs. brei saw led researchers at The Western Sugar Company to conclude that when the brei saw was operated at 1800 rpm (as contractually agreed with their growers), sucrose analyses were erroneously high. The company proposed to lower the brei saw speed to 1200 rpm, which they believed resulted in sucrose determinations more nearly representative of the whole beets from which the sample was obtained. The processing company and grower associations in Colorado, Wyoming, and Nebraska asked the ARS Sugarbeet Research Unit staff to assist them in further investigation and data analysis.

Approach

Because sucrose is not uniformly distributed throughout the sugarbeet, we recognized that there could be an effect of brei saw speed on the sample produced. We began by statistical analysis of a set of data provided by Western Sugar Co. from their preliminary tests. After our analysis of paired data obtained as described above, we recommended an experiment be conducted in which approximately 500 samples of 6-7 sugarbeets each were sampled in a 3-way design: (1) passed over the rasp; beets re-collected and split in half along the longitudinal groove cut by the rasp, then (2) one group of halves passed through the by brei saw at 1200 rpm; and (3) the other group of halved beets passed through the same brei saw reset to operate at 1800 rpm. This experiment was performed by processing company personnel, with grower representatives present, and data for sucrose and several impurity components were provided to us for analysis.

Results

Sucrose determined from samples obtained by brei saw operating at 1200 rpm did not differ from that of samples from the saw operated at 1800 rpm. However, both saw speeds yielded samples that had statistically significantly higher sucrose contents than that of samples obtained with the standard rasp. Similarly, calculated sugar loss to molasses did not differ between saw samples, but values for saw samples were significantly lower than for rasp samples.

Future plans

We have recommended the 3-way experiment be repeated next year with sugarbeet samples from the "early harvest" period, when beets can be expected to contain less sucrose and more impurities than during the standard harvest period. We again will analyze the data and assist the company and grower associations in evaluating and interpreting the results.

SUGARBEET RESEARCH UNIT

Publications

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TERRESTRIAL ECOSYSTEMS REGIONAL RESEARCH AND ANALYSIS (TERRA) LABORATORY

Donn G. DeCoursey, Project Leader
1201 Oakridge Dr., Suite 100
Fort Collins, CO 80525
TEL: (970) 282-5490
FAX: (970) 282-5499

FTS2000: a03npaterra@attmail.com
INTERNET: ddecoursey@terra.colostate.edu

MISSION STATEMENT

To incorporate realistic consideration of land and natural resource management into terrestrial ecosystem components of earth system modeling.

TECHNOLOGY TRANSFER - 1994

Terrestrial Ecosystems Regional Research and Analysis

1. The staff participated in a presentation of TERRA's accomplishments and future plans to the TERRA Board of Directors in May 1994.

2. The professional staff (DeCoursey, Faber, Fox, Goonan, Kersey, Watts and Woodmansee) attended numerous professional meetings, workshops and symposia where different aspects of the TERRA program were presented. Also they have been actively involved in the planning of many of these meetings.

3. Donn DeCoursey organized and conducted an ARS review of its Global Change Program in Norman, OK in February 1994. About 70 ARS and Cooperating Scientists Attended.

4. The Modular Modeling System documentation (draft I) under Donn DeCoursey's guidance was completed and both it and the software were made available to all ARS Scientists over the Internet in July 1994.

5. The Rio Puerco project under Ray Watts' guidance has required numerous contacts with the BLM, BOR, and other agencies. Bob Woodmansee has had numerous contacts with federal agencies, Indian Nations representatives, and state and local representatives in setting up a Field Conference on the Rio Puerco watershed.

6. Donn DeCoursey, in response to a request from the TERRA Board of Directors, prepared an in-depth review of hydrologic and ecosystem scaling and presented it at an ASAE meeting in December.

7. The Active Response GIS under the direction of Brenda Faber has received extremely strong support and she has gotten many requests for demonstrations. She has also been actively involved in using it in helping the Forest Service revising the Land and Resource Management Plans for the Arapaho-Roosevelt National Forest. This has involved facilitating numerous meetings with the stakeholders and the development of associated data bases.

COLLABORATIVE GIS FOR INCREASED EFFECTIVENESS IN RESOURCE PLANNING

Author(s) Brenda Faber[1]

Problem

A Geographic Information System (GIS) is an important tool for resource planning and analysis. However, GIS tools available today are typically complex single-workstation applications used exclusively by trained professionals. Decision makers rarely have direct access to the geographic data and analyses required to negotiate resource planning issues. "Collaborative GIS" is a concept which extends single-user GIS to incorporate *group* interaction with geographic data sets. Collaborative GIS is aimed at helping non-technical decision makers when discussing, exploring, and negotiating resource alternatives.

Approach

A collaborative GIS prototype was developed by adding a geographic framework to a commercially available Electronic Meeting System product. The prototype provides an interactive, real-time environment for teams of resource managers to debate land allocation issues. Participants are electronically "linked" through a local area network configuration of laptops. Participants can interactively explore geographic data layers and construct potential geographic scenarios. The implications of these scenarios are modeled and discussed with the group as the scenarios are suggested. Decision rationale for final recommendations are recorded automatically and linked to the original geographic data sets.

The prototype was tested in a pilot study with the USDA Forest Service for finalizing the Arapaho-Roosevelt National Forest *Land and Resource Management Plan Revision.* District rangers and their staffs used the collaborative GIS prototype to explore district priorities, review a database of public comment, assess consistency of management strategies across the Forest, and recommend changes to management prescriptions and/or general policy.

Results

Initial study results were positive. Participant evaluations indicated increased ownership of process results and a greater sense of control in the process itself. Applying and displaying changes, as they were recommended, was very significant in establishing group consensus.

Future plans

Continued development of the collaborative GIS prototype will include the integration of ecosystem assessment models into the system. In addition, work is underway with the Colorado State University Psychology Department to investigate the impact of using collaborative GIS on perceptions of social justice in planning and policy negotiations. Existing research in social justice indicates that increased perceptions of "voice" (i.e. active individual contribution) are correlated with increased perceptions of fairness, and acceptance of both favorable and unfavorable process outco

[1]CIESIN/TERRA Lab

MODULAR MODELING SYSTEM

Author(s)

Donn G. DeCoursey

Problem

Numerous mathematical models of physical, chemical and biological processes have been developed at many different spatial and temporal scales. These models have been used to solve numerous problems, but issues such as global change, resource sustainability, and environmental implications require the integration of models from many disciplines as well as the desirability of making the numerous models available to all scientists. These problems and issues require changes in the models that will insure compatibility and linkage. These changes need to be accomplished in a way that minimizes the effort involved.

Approach

A modular modeling system has been developed over the past several years by George Leavesley (USGS-WRD) and Pedro Restrepo formerly with the Center for Advanced Decision Support for Water and Environmental Systems (CADSWES). It automatically links selected modules, runs the assembled collection of modules, and presents the results in graphical and three dimensional displays. This system had the potential to provide a solution to the problem. However it included only hydrologic models and needed several refinements. Models dealing with other ecosystems, chemicals, and physical processes at a range of spatial and temporal scales are needed. The graphical output required changes. A feedback system that enables iterative solution between modules within a time stem was needed. The space/time loops needed to be reversed. The System needed to be linked to a GIS to work with spatial input and output data. In-house and contract efforts were arranged to help solve these problems.

Results

A users guide to MMS was completed and the system was released to ARS scientists in July of 1994. The link to a GIS (GRASS) was completed and is in the latest version. An approach to providing feedback is also incorporated in the latest version of MMS and is being beta-tested. The basis for a change in the space/time loops was developed and will be incorporated in an Object Oriented version underdevelopment. The revised universal soil loss equation (RUSLE) has been added as a module.

Future plans

Future work will be focused on two efforts. The first will be to add more modules of other ecosystems and biological and chemical processes. Initial efforts will be to add flow routing and sediment transport processes for application in the Rio Puerco Watershed Project. The second major effort will be the continued refinement of MMS. This will be centered on the development of an Object Oriented version of MMS that will incorporate the revised space/time loops.

ECOLOGICAL INFLUENCES ON SEDIMENT PRODUCTION IN THE RIO PUERCO BASIN OF NEW MEXICO

Author(s) Raymond D. Watts[1], Simon Lee[1] and Robert Woodmansee[2]

Problem

The Rio Puerco Basin of New Mexico is one of the highest sediment-producing basins of the United States. During the period 1880-1930 the Rio Puerco excavated an extensive network of deep arroyos and delivered particularly large quantities of sediment to the Rio Grande. If sediment production of that period had been sustained, the Elephant Butte Reservoir (the major storage and control structure on the middle Rio Grande) would be 80% full of sediment today. 75 years of research have not yielded conclusive answers to the following questions: (1) was the high erosion initiated and maintained by climatic conditions, by grazing, or by both; (2) were upland or channel conditions, or both, critical to the initiation and maintenance of erosion; (3) what conditions would lead to a new period of high erosion; (4) what management measures might be applied to uplands and channels to (a) enhance arroyo healing and (b) prevent renewed incision.

Approach

Earlier research has focused on historical and natural records; interpretation of these records has been ambiguous. We are building an interdisciplinary numerical model to describe the transport of water and sediment in the basin, the effect of vegetation on water and sediment transport, and dynamic vegetation response to climate and water availability (in the channels, water availability depends on weather events in other parts of the basin). Our objective is to test hypothetical conditions of climate, grazing, and vegetation that could initiate and maintain erosion in the basin. We will provide these results to land- and water-management agencies and assist them in developing management strategies for the Basin.

Results

Model building is in progress; current work is concentrated on the transport of water and sediment within the channels. GIS work is under way to provide parameterizations of catchments and channels. No results are yet available.

Future plans

A field conference (May 1995) is being organized by R. Woodmansee as a step toward developing an interdisciplinary cadre of scientists who appreciate the full spectrum of ecological, meteorological, and geomorphological interactions. A year's additional work is required in order to incorporate vegetation, grazing, and weather models. Simulations will be done at multiple resolutions in order to determine requirements for spatial and temporal representations of the basin. Hypothetical conditions will be established by working with collaborators from BLM, USGS, USBR, UNM, and others, then simulations will be done to examine thresholds of system instability.

[1]US Geological Survey/TERRA Lab
[2]Colorado State University/TERRA Lab

SCALING HYDROLOGICAL, CLIMATOLOGICAL, AND ECOLOGICAL SYSTEMS

Author(s) Donn G. DeCoursey

Problem

The modern science of hydrology is built on a foundation of process knowledge; tremendous advances have been made in understanding infiltration, evaporation, sediment transport, and subsurface water and chemical transport at small space-time scales. However we cannot represent as well the soil-plant-atmosphere continuum at larger scales. Extrapolation of theories of non-linear hydrological processes to large scale, three dimensional systems such as major river basins, flood plains, ecosystems and wetlands continues to be a problem. Yet recent concern for the possible effects of climate change on agricultural production, ecosystems and water quality and quantity; the effects of agriculture on large river systems; and the anthropogenic effects of changes in our environment on weather and climate require that we concentrate on understanding large scale hydrology. Thus new approaches and theories are needed to scale the time/space continuum and deal with these consequences of our changing environment.

Scaling encompasses many concepts: process descriptions, cartographic considerations or pattern analysis, and spatial and temporal effects. It is not simply integration or aggregation of values at one level to achieve estimates at a more encompassing level of consideration. Rather scaling represents the transcending concepts that link processes at different levels of space and time. It entails a change upward that identifies major factors operational on a given scale of observation, their congruency with those on the lower scale, and the constraints and feedbacks on those factors.

Approach

This investigation is an initial effort to learn more about scaling as applied to problems of climate change and system sustainability. Thus it is a literature review of hydrological, climatological and ecological systems scaling.

Results

It appears that almost all model related papers discuss the issue of scale at some point, thus the potential number of papers to review is tremendous. In this review the emphasis in hydrology was placed on physical hillslope and catchment models and multiscaling as applied to the temporal and spatial features of rainfall and flood peaks. The focus of the review on catchment models was on distributed and macro scale versions of the topo-soils index and its relationship to measures of dimensionless hydrologic similarity. The concept of a representative elemental area was also investigated. Forest, range and cultivated ecosystems models were briefly described along with problems of integration that involves the addition of new phenomena as scale is increased. Constraints in model development, sources of uncertainty, and methods of reducing model dimensionality are discussed. Several comprehensive examples of ecosystems models that enable the effects of nonlinear internal processes to impact response are described. Review of climatological scaling focused on the structure of the soil-vegetation-atmospheric components of GCM's, problems of scaling the *big stomata* type models and the significance of landscape patchiness at the subgrid scale on large scale (GCM) model response.

Future plans

The draft review that was presented at a recent ASAE meeting and is available for distribution, will be summarized and submitted for publication in the ASAE Journal.

TERRESTRIAL ECOSYSTEMS REGIONAL RESEARCH AND ANALYSIS (TERRA) LABORATORY

Publications

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WATER MANAGEMENT RESEARCH UNIT

Dale F. Heermann, Research Leader
Agricultural Engineering Research Center
3317 W. Vine Drive
Colorado State University
Fort Collins, CO 80523
TEL: (970) 491-8511
FAX: (970) 491-8247

FTS2000: a03dfheermann@attmail.com
INTERNET: dale@lily.aerc.colostate.edu

MISSION STATEMENT

Research emphasis is to integrate applied and basic principles to develop improved water, chemical, and alternative weed management systems and irrigation system designs. Improvements are directed toward sustainable, environmentally sound, and efficient systems based on soil, water, fertility, energy, and weed ecology principles. This encompasses understanding physical and biological phenomena and developing computer simulation models and expert systems to transfer new technologies to producers, consultants, action agencies, industry, and scientists.

TECHNOLOGY TRANSFER - 1994

Water Management Research Unit

1. Walter Bausch was a member of an ASAE subcommittee (Tom Ley, Ron Elliott, Walter Bausch, Paul Brown, David Elwell, Bert Tanner} within SW-213 (Evapotranspiration Committee) to develop measurement and reporting practices for automatic agricultural weather stations. The development of these guidelines has broad support and participation by individuals from several groups including the ASCE Irrigation Water Requirements Committee, American Association of State Climatologists, American Meteorological Society, American Society of Agronomy, National Weather Service, USDA-ARS, US Forest Service, USDA-SCS, and US Bureau of Reclamation.

2. Bausch made a presentation at ARDEC on remote sensing of plant nitrogen status to participants of 1st Annual South Platte Ag Tour.

3. Bausch and Ed Schweizer presented Water Management Research activities to visiting scientists from AgCanada.

4. Gerald Buchleiter, Dale Heermann, and Harold Duke are involved in a Cooperative Research And Development Agreement with Valmont Industries to extend the capabilities of base station software of their monitor and control system and to develop and test a pulsing, low volume spray system that is mounted on a self propelled sprinkler system. A main objective of this agreement is to reduce the time lag for implementing research results into a commercially available product.

5. Gerald Buchleiter gave a presentation on sprinkler irrigation research to the Western States Irrigation Workshop, which is composed of Natural Resource Conservation Service (SCS) state irrigation engineers and agronomists for the 17 western states. His main focus was on the unit's current research to automate self propelled sprinkler systems and to interface decision support models with commercially available monitor and control systems. This workshop provides an excellent opportunity to interact with NRCS personnel on implementing results of current research.

6. Buchleiter and Duke provided technical support to several Cooperative Extension agents who publish regional crop water use information and work with farmers individually on irrigation scheduling.

7. Duke has collaborated with CSU Plant Pathology and Atmospheric Science to develop a statewide network of more than 25 agriculturally oriented meteorologic stations. He has served as administrator of the network for three years, collecting data via hardwire and cellular telephone each day. Data are summarized automatically and both summary and raw

data made available over Internet and by a dialup bulletin board system. Analyses based on these data, including crop evapotranspiration estimates and projections of plant pathogen and insect outbreaks are also made available daily. During the first season of operation the information was accessed more than 1700 times by researchers and growers.

8. Working with colleagues in CSU Extension Service, Duke and J.R. Welsh have cooperated in a multidisciplined effort to provide virtually immediate delivery of time sensitive information directly to Colorado growers. CSU has developed a pilot project with two commercial satellite subscription services which together serve some 2000 producers in Colorado. The group provides information on local weather conditions, crop water use estimates, timely production information, and digital images illustrating such timely topics as destructive insects and plant pathogens. Post-season surveys in 1993 and 1994 indicated that Colorado farmers estimated an average benefit of this information to their production operations in excess of $1400 and $1900 annually, respectively.

9. Duke has made numerous presentation to farmer groups, NRCS technical personnel, and Four-States Irrigation Council on irrigation water management issues. He serves on the USGS Upper Colorado River National Water Quality Assessment advisory team, CSU's ARDEC management committee, and is the engineering representative to the ARS Patent Advisory Committee for Northern Plains, Southern Plains, and North Central Areas.

10. Dale Heermann's activities with the Partnership between ARS and NRCS(formerly SCS) has not progressed as originally envisioned. Considerable interfacing was accomplished on the FOCS program and planning was done on future ways of enhancing the Partnership. Considerable effort was devoted to rewarding ARS scientists for Team Research which could significantly enhance the development of new products and the technology transfer to field offices. The reorganization of the NRCS has made it unclear as to how this can be continued. Heermann's personal involvement is now limited to working with individuals within NRCS on programs they feel is essential for their mission. The programs will be in the area of design and evaluation for center pivot irrigation systems.

11. Lori Wiles and Ed Schweizer, in conjunction with scientists from Colorado State University, Michigan State University, and the University of Minnesota prepared a manual for the GWM model. The manual and distribution disks were sent to all members of NC-202 and manuals to a number of libraries. Additional copies are available to any interested party.

12. Roger Smith has distributed and supported a large number of users of the Opus model for agricultural water/plant/soil systems. There are several users in Germany, Estonia, Australia, Portugal, Spain, England, as well as the United States. More than a hundred copies of the documentation have been shipped, and an updated version of the computer code has been offered to all users. Applications of the model have been primarily the investigation of environmental risk for various chemical applications and nutrient leaching. Many of the applications are in research investigations, but others have apparently been management oriented. Users have found a few cases where bugs in the program have shown

up and have been corrected. The model has been extended to operate in the reverse season phasing of the southern hemisphere.

13. Smith has also had considerable technology transfer activity with regard to the runoff and erosion models KINEROS and EUROSEM. These are related models for watershed runoff and erosion, the latter being a joint effort with a research consortium sponsored by the European Community in Brussels. These models have been used both in engineering analyses and in research efforts here and in the European community countries.

PLANT NITROGEN STATUS ESTIMATED FROM CANOPY REFLECTANCE

Author(s) W. C. Bausch, H. R. Duke, D. Westfall[1], and G. Cardon[1]

Problem

Water quality issues concerning excessive nitrates in ground and surface water supplies are impacting nitrogen management in many agricultural areas. Small applications of nitrogen as needed by the crop have tremendous potential for reducing nitrate contamination of ground water. Various techniques have been developed to determine plant N status. However, these techniques are laborious, time consuming, and represent point measurements. Remote sensing can sample a plant community rather than a single plant and can rapidly assess the spatial variability that exists in a field. Leaf reflectance at various wavelengths have been correlated to leaf chlorophyll concentration; unfortunately, applications have not been developed for monitoring N status at the plant canopy level.

Approach

Irrigated corn with various nitrogen treatments was used to obtain reflectance data to correlate with leaf N concentration and chlorophyll measurements. Canopy reflectance was obtained in the blue, green, red and near-infrared wavebands using Exotech four-band radiometers positioned perpendicular to the crop surface. Chlorophyll measurements were made with a SPAD meter; plant tissue samples (leaf punch) were taken at the time of SPAD measurements for plant N analysis. All measurements were taken throughout the growing season. SPAD values were calculated as a N sufficiency index (SPAD reading ratio) where the reference was a heavy N treatment.

Results

Data from two growing seasons consisting of three varieties were analyzed. Various combinations of reflectance data from the four wavebands were calculated to compare with the SPAD data. The near-infrared/green (NIR/G) ratio appeared best; the G band responds well to crop greenness whereas the NIR band responds to plant biomass (leaf area). A reflectance index was formed by normalizing the treatment data with the reference data. The reflectance index plotted against the N sufficiency index produced a curvilinear relationship. Reflectance data acquired prior to the eight leaf growth stage (soil background was the dominate factor in the crop/soil scene) contributed to the nonlinearity as well as data acquired from a severely deficient N treatment. Elimination of these data produced a near 1:1 relationship. Correlation of the reflectance index with plant tissue total N was similar to the correlation of the N sufficiency index and plant tissue total N.

Future plans

Data from the 1994 growing season (once completely analyzed) will be used to determine the extent of tissue sampling for plant N to relate to canopy reflectance, i.e., tissue samples from the most recent mature leaf as opposed to sampling from leaves throughout the canopy. Canopy reflectance acquired at an oblique angle instead of perpendicular to the canopy may minimize soil background effects; this will be investigated. Plant N status as determined by remote sensing and GPS will be input to a GIS for spatial variability analysis and data manipulation to develop a nitrogen management scheme for spoon feeding nitrogen as needed by an irrigated corn crop via a linear move sprinkler system.

[1]Soil and Crop Sciences, Colo. State Univ.

EVALUATION OF PHYSICALLY BASED ET MODELS

Author(s) W. C. Bausch and H. J. Farahani

Problem

Evapotranspiration (ET), the sum of evaporation (E) from the soil and transpiration (T) from the plant, is a major component of the water budget for agricultural lands. As long as direct measurement of ET is difficult and costly, mathematical modelling remains essential. Consequently, dynamic models capable of describing the entire range of crop cover are required to simulate ET processes for crop systems.

Approach

Data for evaluating the single-layer Penman-Monteith (PM) and the two-layer Shuttleworth-Wallace (SW) ET models were collected at ARDEC, Animal Sciences Farm during the 1993-94 growing seasons. Grain corn was planted in a furrow irrigated field with 400 m length rows. Crop ET was measured using the Bowen ratio energy balance (BREB) method. Required climatic data for the ET models were measured over the crop at the BREB measurement site. Leaf area was measured on ten randomly selected plants around and near the BREB site throughout the growing season to calculate leaf area index (LAI). Stomatal resistance was measured at midday on all leaves of six randomly selected plants before and after irrigations and a few times between irrigations.

Results

Growing season ET (1993) as measured by the BREB method was 517 mm. Estimated seasonal ET with PM and SW models were 365 mm and 515 mm, respectively. For LAI < 2, the PM model under-predicted ET by 53 % while the SW model under-predicted by 5%. At LAI > 2, PM performance greatly improved as soil evaporation became less significant (17 % under-prediction); the SW model over-predicted accumulated ET by 2%. The SW model partitioned ET into 139 mm E and 376 mm T. Seasonal E was estimated at 27% of seasonal ET which is in agreement with data in the literature. Unfortunately, the SW model requires an intense level of input data to evaluate the required resistances. A limited sensitivity analysis on some of the resistance inputs showed that 1) the soil water resistance can be taken as a constant set to 250 s/m without sacrificing accuracy (estimated seasonal ET = 520 mm) and 2) the mean canopy boundary layer resistance can be calculated from values of 10 to 25 s/m with little variation in estimated seasonal ET (516 to 510 mm, respectively). However, the bulk stomatal resistance of the canopy calculated as a function of effective LAI is very sensitive. If set to one half actual LAI, seasonal ET = 490 mm; if set to actual LAI, seasonal ET = 632 mm. Reliable ET estimates were obtained assuming all leaves contribute to transpiration at LAI < 2, and at LAI > 2, effective LAI is 1/2 actual LAI. This forms a discontinuity at LAI = 2; ideally, a continuous function is needed to describe effective LAI.

Future plans

ET models will be evaluated with the 1994 data to determine if similar responses exist. Develop simplified relationships or constant values for some of the resistance formulations to make the SW model more useful. Evaluate the goodness of the SW model using climatic data measured from a nearby automated weather station. Develop a continuous function to estimate effective LAI as a function of actual LAI. Investigate the use of canopy reflectance to estimate effective LAI throughout the growing season to include the spatial variability of crop growth on ET.

REAL-TIME CROP COEFFICIENTS FOR CORN USING CANOPY REFLECTANCE

Author(s)

W. C. Bausch and G. W. Buchleiter

Problem

Irrigation scheduling computer models utilize reference ET calculated from measured climatic data and crop coefficients to estimate actual crop ET. This two step process is widely used and is the most practical field method to date. Crop coefficients used to adjust computed reference ET for a specific crop are based on averages of several years data and reflect 'average' crop development rates. Whenever crop growth deviates from this 'average' rate, the traditional crop coefficient may be in significant error. Consequently, actual crop ET may be different than estimated which could result in over- as well as under-irrigation.

Approach

Various crop coefficient curves that have been developed for corn were selected to evaluate their 'goodness' to estimate corn ET throughout the growing season. Corn ET was measured using the Bowen ratio energy balance (BREB) method in a field of furrow irrigated corn at ARDEC, Animal Sciences Farm. Canopy reflectance of the crop/soil scene in two specific wavebands (red and near IR) was computed from measurements of reflected and incoming light using intercalibrated Exotech radiometers. Reflectance in the red and near IR was used to compute the soil adjusted vegetation index, an index that minimizes soil background effects. A reflectance-based crop coefficient was calculated from this vegetation index on each day of data acquisition. Leaf area and soil moisture were also measured around and near the BREB measurement site.

Results

Data for the 1993 growing season were analyzed and reported in the 1993 annual report. 1994 growing season data have not been analyzed; these data represent a different corn variety and different growing season conditions than did the 1993 data.

Future plans

The 1994 data will be analyzed and compared to the 1993 data. The reflectance-based crop coefficient will be computed based on crop coefficients calculated from measured BREB ET and reference ET calculated using the Penman-Monteith ET equation. The reflectance-based crop coefficient will be developed using fraction of season growing degree days accumulated to black layer for its driver. Efforts will be made to integrate the reflectance-based crop coefficient into the irrigation scheduling program so that spatial variability of crop growth can be taken into account for estimating crop ET.

WEED SEEDLING IDENTIFICATION AND MAPPING USING DIGITAL IMAGING

Author(s)

W.C. Bausch, E.E. Schweizer, M.S. Howarth[1], L.J. Wiles, P. Westra[2], P. Ayers[3], H.R. Duke

Problem

Excessive herbicide use to control weeds has been the norm rather than the exception. Consequently, some of these chemicals have been detected in surface and ground water supplies. Herbicide applications would be more efficient if chemicals were applied only where weeds existed. Weed seedling identification and mapping is feasible through digital imaging, GPS and GIS techniques.

Approach

Images were collected in the greenhouse as well as the field. The greenhouse was used to control growth and minimization of shadows cast by the seedlings during imaging sessions. Corn, wild prosso millet, and velvetleaf were grown in the greenhouse; images were acquired with a 35 mm camera using color slide film which when developed was converted to digital format and stored on CD-ROM. A field study using the same species were imaged with the 35 mm camera and a still digital tri-camera system filtered in the green, red and near-infrared with optical bandpass filters.

Results

An image analysis program was written to calculate four size and 11 shape features from binary images. Selected greenhouse images (plants without occluded leaves)of the three plant species were analyzed. Velvetleaf (dicot) was completely separated from wild prosso millet and corn (monocots) using projected perimeter and the first invariant central moment of inertia ($ICMI_1$). Actually, velvetleaf can be distinguished from the two monocots by simply setting a threshold on $ICMI_1$ since the data from the monocots were never within the range of the velvetleaf data. A two step process was required to distinguish wild prosso millet from corn. Projected perimeter was used to estimate plant age (days after emergence). Estimated age, projected length, and circularity were then used to separate wild prosso millet from corn. A procedure was developed to register the green, red and near-infrared images from the digital tri-camera system to obtain a pixel for pixel match.

Future plans

Additional images will be analyzed using Optimas (an image analysis program) to further develop the separation schemes for robustness. These classification algorithms will be tested and validated using independent data. The pixel resolution required to distinguish objects will be determined by imaging weed seedlings from several heights above the target. GIS weed maps (manually identified by humans, images taken also along with GPS over same location) will be developed for experimental plots at ARDEC. Post emergence weed management decisions will be made based on the bioeconomic weed/crop model GWM. Based on computer simulations and weed population dynamics, spatially variable rates of herbicides will be applied with an experimental ground applicator and with the linear move sprinkler irrigation system.

[1]Atlas Pacific Inc., Pueblo, CO; [2]Dept. of Weed Sci. & Plant Path; and [3]Dept. of Chem. & Bioresources Engr., Colo. State Univ.

REAL-TIME MANAGEMENT OF SELF-PROPELLED IRRIGATION SYSTEMS TO CONSERVE WATER

Author(s) G.W. Buchleiter, H. R. Duke, W.C. Bausch, D.F. Heermann, D. Nielsen

Problem

Profit squeeze and increased awareness/accountability for environmental damage from inefficient crop production practices are encouraging producers to seek technologies which improve their management capabilities for sustainable production and which apply crop production inputs more judiciously. Each year is sufficiently different to require management decisions to be made on a timely basis throughout the growing season. Producers want more timely, site-specific data on which to base their daily or weekly management decisions, but many are unwilling or unable to spend the additional resources to obtain additional data necessary for complex models. Many irrigation systems do not have the necessary capabilities to efficiently implement complex decisions on a timely basis to capture the benefits of improved recommendations.

Approach

The current research focuses on problems of real-time decision making at the field level and is not intended to replace sound annual or multi-year planning. An integrated system is envisioned which: (1)reduces resources required for obtaining necessary data, (2) processes data quickly and efficiently, (3) analyzes the data to make appropriate recommendations, and (4) implements the producer's decision in a timely manner. Various scientists are involved with research in each of the 4 components of the integrated system.

Results

A Global Positioning System (GPS) was used successfully to instantaneous record locations of remotely sensed data within 2 - 2.5 meters 95% of the time. Geographical Information System (GIS) technology was investigated as a means of efficiently processing and maintaining complex databases describing spatial variability at the field level. Microcomputer software for recommending irrigation timing and amounts is being enhanced to include additional capabilities for determining crop water use, easy updating of model recommendations based on actual crop conditions that are remotely sensed, output in a graphical format, and user-friendly interface with commercially available computerized monitor and control equipment.

Software was developed for communicating from the base station through the primary computerized monitor and control system to an auxiliary controller which differentially applies water by pulsing inflow to each half span of the linear move machine. Pumping rates, water application uniformities, and control capabilities were evaluated for the linear move machine at Akron to assess it's suitability for field experiments on alternative crops and cropping sequences.

Future plans

A pilot project to demonstrate and evaluate GIS capabilities for processing spatially variable data is planned under the linear move at ARDEC. Data from a 3 year water and nitrogen study will be used to validate the irrigation management model. Testing and evaluation of the system to differentially apply water will be continued. Computer simulations for the linear move at Akron will determine modifications for improving sprinkler performance and control capabilities.

DESIGN AND DEVELOPMENT OF SOFTWARE FOR COMPUTERIZED MONITOR AND CONTROL EQUIPMENT FOR SELF PROPELLED SPRINKLERS

Author(s) G.W. Buchleiter, D.F. Heermann, R.Unruh[1] and D. Mack[1]

Problem

Customers having computerized monitor and control systems which operate multiple self propelled sprinklers from a single microcomputer, are demanding easier access to collected data so it can be used more effectively in making real-time management decisions. Researchers are interested in implementing research findings about improved irrigation management practices on a commercial farms.

Approach

A cooperative research and development agreement (CRADA) exists between USDA-ARS and Valmont Industries, a major center pivot manufacturer, to shorten the production time for research results on improved management of center pivots to be available and adopted on the farm. Software programming is done jointly so researchers know how to access data collected by a monitor and control system for use in decision support programs. The manufacturer recognizes the value of the additional benefits that their product can provide if used conjunctively with improved management.

Results

Restructuring of base station software with a totally graphical interface for controlling multiple self propelled irrigation systems was completed and field tested at the Agricultural Research, Demonstration, Education Center (ARDEC). Work is in progress on a prototype WINDOWS version which will satisfy Valmont's product development plans to move towards a multi-tasking environment as well as enable additional management modules developed by researchers to be more easily integrated into the commercially available system.

Several methods for determining the position of the linear move machine in the field were tested for accuracy and reliability by comparison with visual observations and measurements. Position was calculated at the base station based on information received from the computerized control panel which recorded sensed field locations, run time of the cart tower, and revolutions of a measuring wheel. Modifications to the electronic circuitry and the base station software were necessary to improve the reliability of detecting when the machine passed known field locations.

Future plans

Work on the prototype WINDOWS version of base station software will continue. The irrigation scheduling program will adapted and operational data summarization modules developed for the WINDOWS environment. The capability to operate the base station via telephone from a remotely located computer will be added and tested at ARDEC in 1995. A graphical user interface using a mouse to program sprinkler operations is envisioned as an alternative to the current sprinkler programming procedure which uses menus. Depending on marketing analyses, alternative modes of communication such as satellites, infrared, and cellular phones may be investigated as alternatives to the radio telemetry that is currently used.

[1]Valmont Industries, Valley, NE

PERFORMANCE EVALUATION OF *RZWQM* FOR SPRINKLER IRRIGATED SANDY SOILS

Author(s) G.W. Buchleiter and H. Farahani

Problem

Irrigated agriculture is a big contributor to non-point pollution and water quality problems in the United States. Comprehensive field experiments to determine improved management practices are time consuming and expensive. Sophisticated computer models developed by researchers are tools that can be used to manage water resources more efficiently while reducing adverse environmental impacts. These models must be validated for a variety of climatic regimes and crop production systems to gauge their usefulness.

Approach

The Root Zone Water Quality Model (*RZWQM*) is a process-based model integrating fundamental physical, chemical, and biological processes of a general crop growing environment, that was developed by ARS to assess the impact of agricultural practices on surface and groundwater quality. Since comprehensive data sets for all of the various processes are difficult to obtain at a single site, the validation process is divided into smaller studies which focus on particular processes. The current study focuses primarily on crop water use, soil water, crop production, and percolation of water and nitrate through the root zone. A mass-balance approach is used for both the soil water and nutrient aspects. The double-layer evapotranspiration model predicts potential evaporation from bare soil and residue and crop transpiration on a daily basis. Actual rates of water use are determined by the ability of the soil to deliver potential rates as determined by the Richards' Equation for soil evaporation and the root water uptake function of Nimah and Hanks for crop transpiration. A generic crop production model is used to predict plant growth and population dynamics to changes in environment and management practices. Seven output parameters identified as indicative of balanced model performance include crop water use, average soil moisture in the root zone, percolate below the root zone, nitrate leached below the root zone, N-uptake, grain yield, and biomass production.

Results

Data collected on a commercial farm in northeastern Colorado for one growing season were used to parameterize the model. The most critical parameter in the plant growth submodel was the plant biomass per unit of leaf area index. Measured soil moisture amounts indicated a higher water holding capacity than expected using soil textural classifications. Using independent data from the same site for the next growing season, differences between predicted values and measured values ranged between 5 and 22% for the seven performance criteria indicating acceptable model performance.

Future plans

Additional evaluations which consider spatial variability within fields are anticipated using data collected from the same field and several other fields in the area. Simulation runs for the parameterized model will be used to evaluate alternative irrigation and fertilizer scheduling to minimize nitrate leaching. These data can also be used in evaluating other process-based models to identify possible simplifications of data requirements.

REAL-TIME MANAGEMENT OF NITROGEN FERTILIZER UNDER IRRIGATED CONDITIONS WHICH IMPROVE WATER QUALITY

Author(s) G. W. Buchleiter, W.C. Bausch, and H.R. Duke

Problem

Because nitrates are very soluble, effective nitrogen management under irrigated conditions is closely related to good water management. Producers' attitudes to provide excess nitrogen as insurance is not conducive to improving water quality. Normal climatic variations during the growing season may require producers to make adjustments in their nitrogen applications for near optimum production while minimizing nitrogen losses from deep percolation. Spatial variability of nitrate levels within a field complicates decision making if the producer is attempting to minimize or reduce water quality degradation due to deep percolation. In keeping with the customers' (primarily producers, consultants) constraints, required data must be readily obtainable and affordable.

Approach

An adequate characterization of spatial variability is necessary for efficient and effective management. Data indicative of the plant's nitrogen status must be collected and processed quickly and efficiently . A Geographical Information System (GIS) efficiently links the nitrogen status data with the spatial variability within a field and can be coupled with simple process based models to identify areas requiring timely management decisions. The final product is output, much of which may be graphical, that the producer can understand and implement as necessary during the growing season.

Results

Chlorophyll amounts which are indicative of nitrogen in plant tissue were measured with a SPAD meter and correlated with canopy reflectance in the green and near-infrared spectral wavebands that was remotely sensed on plots of the water nitrogen study at ARDEC. A Global Positioning System (GPS) using differential correction post processing, was used to instantaneously locate the field measurement points of the remotely sensed data with an accuracy of 2 - 2.5 meters.

Future plans

Evaluations currently underway, will identify the appropriate algorithms to describe the various components of a nitrogen budget. Microcomputer software currently being developed, will make recommendations on nitrogen management in conjunction with improved water management practices during the growing season. Procedures will be incorporated to use remotely sensed data indicative of the crop's nitrogen status to update predictions. Additional testing on the accuracy of GPS is planned to determine whether it is suitable for establishing the base GIS map. GIS will be utilized to track both temporal and spatial variabilities within a field and present output in an easily understood format.

REAL-TIME MANAGEMENT OF NITROGEN FOR WATER QUALITY PROTECTION

Author(s) H.R. Duke, W.C. Bausch, G.W. Buchleiter, D.F. Heermann, G.E. Cardon[1], D.G. Westfall[1], J.A. Chapman[2]

Problem

Fertilizer nitrogen is potentially a major source of groundwater contamination, but is necessary for sustained economic viability of production agriculture. When readily soluble nitrogen is applied uniformly across a field early in the season, precipitation or poorly managed irrigation can leach the nitrogen beneath the developing root zone and preseason estimates of required fertilizer may result in residual N which can be leached during the winter. Areas of lower water holding capacity are particularly vulnerable to leaching from uniformly applied water and chemicals.

Approach

Field studies at CSU's ARDEC are designed to evaluate, over the long term, the impact of management of fertilizer nitrogen and irrigation water on a real-time basis. Three nitrogen treatments and two water treatments are imposed on replicated plots under both a linear sprinkler irrigation system and furrow irrigation. Water status is measured at least weekly and estimated by meteorologic methods daily. Crop nitrogen status is estimated on a weekly basis from soil samples, plant tissue samples, a chlorophyll meter, and by remotely sensed canopy reflectance to evaluate both spatial and temporal variability. The chlorophyll meter is used to trigger weekly nitrogen applications as required to meet crop needs. The other data are post-processed for correlation with one another to verify validity of low-input methods for real-time management. Both hardware and computer systems are under development to deliver water and nitrogen on a spatially variable basis.

Results

The first year of field studies has been completed. High residual N levels partially masked the N treatments in 1994, but some yield differences were noted. Plots fertilized on a real-time basis yielded slightly more grain with significantly higher yield per unit total available N, producing 97 kg grain/kg N compared with 86 kg/kg N for the side-dressed treatment and 83 kg/kg N for the preplant fertilized treatment. Most significant differences were observed under plots which received irrigation applications in excess of computed crop evapotranspiration, even for the fine textured soils of the ARDEC site. Remotely sensed reflectance ratios of the green to near infrared bands show high correlations with both tissue N analysis and the chlorophyll meter.

Future plans

The plots at ARDEC will be maintained for 3 to 5 years, with the same treatments applied to the same plots each year. The results of the plot studies will be used to develop water and fertility management strategies that result in minimum potential leaching from precipitation or excess irrigation. Data will be used to verify portions of a real-time nitrogen/water management model under development. Annual soil sampling to 3 meters will be used to estimate the N balance on each plot to evaluate the effectiveness of fertility treatments and water management scenarios for efficient crop use of available nitrogen.

[1]Dept. Crop and Soil Sci., Colo. State Univ.; [2]Valmont Industries, Valley, NE

SPATIALLY AND TEMPORALLY VARIED WATER & CHEMICAL APPLICATION

Author(s) H.R. Duke, W.C. Bausch, G.W. Buchleiter, D.F. Heermann, D.G. Westfall[1]

Problem

It has been long recognized that soils are an extremely variable medium. Even within a single series, the spatial variability in properties is known to be very large and to change temporally. When chemicals and irrigation water are applied uniformly across a field, some areas may receive insufficient application for optimum production and others more than can be utilized before it is lost to percolation. If excess amounts are applied to assure against deficits, amounts not leached during the season will remain as residuals subject to leaching from precipitation between growing seasons. Thus, there is a potential to improve the utilization of both water and chemicals, thereby reducing environmental degradation, by applying water and chemicals only when and where needed.

Approach

Twenty four plots have been established at CSU's ARDEC under a linear-move sprinkler system, and the same number under an adjacent surge irrigated plot. Two water treatments, based on computed crop evapotranspiration, are applied: 100% Et and 150% Et. Three fertility treatments applied are preplant application, preplant starter with sidedress,and preplant with supplemental application as indicated by real time measurements. Applications are scheduled by measurements made in each plot with a chlorophyll meter. Simultaneously, remotely sensed canopy reflectance is measured from a high clearance tractor platform, and both soil and tissue samples are collected for laboratory analysis. Remote controls for the linear move sprinkler are being modified to control devices to apply both water and chemicals on a site-specific basis across the field.

Results

Even though the soils in the study area appear quite uniform, intensive soil sampling has shown a wide range of available nitrogen. After uniform treatment during the 1993 season, N fertilizer recommendations ranged from an excess to a deficit of more than half the projected need. Resulting crop yields were not significantly different from any of the treatments, and fertilizer N efficiency was not different for the 100% Et water treatments. However, where irrigation applications were in excess of Et, nitrogen use efficiency was significantly greater for plots which received N in response to depressed chlorophyll readings. Post-harvest soil sample analysis has not been completed, but is expected to indicate lower residual N than in areas receiving all N by "layby."

Future plans

Both water and fertility treatments will continue to be applied to the same plots for 3 to 5 years in order to evaluate the "equilibrium" response to fertility and water treatments. Each preseason plot treatment will be based on a composite sample from at least three locations within the plot, with fertility recommendations based on the newly developed algorithm of Univ. NE. Pre- and postseason soil sampling will be used to evaluate overwinter leaching of nitrates. As soon as confidence in the remote sensed indication of pending N deficiency can be demonstrated, that technique will replace the chlorophyll meter for real-time scheduling. Low volume, site specific application of herbicides will be explored using the sprinkler irrigation system .

[1]Dept. Crop and Soil Sci., Colo. State Univ.

HARDWARE AND SOFTWARE FOR VARIABLE WATER AND CHEMICAL APPLICATION

Author(s) H.R. Duke, G.W. Buchleiter, D.F. Heermann, J.A. Chapman[1], R.R. Unruh[1]

Problem

Application of both water and chemicals in response to spatially variable measured parameters has potential for reduced potential for environmental degradation as well as reduced material costs for the producer. Although commercial equipment and services are used in the Upper Midwest for preseason application of chemicals on a spatially-varied basis, little work has been done to develop equipment and decision aides for in-season, spatially varied application of water and chemicals under irrigated agriculture. Chemigation systems have had some success at chemical application using relatively high volumes of water. The PASS system and automated systems developed in Idaho show promise for spatially variable application, but are relatively expensive. Using the irrigation system to apply chemicals allows application at any time, regardless of crop development or weather conditions and reduces operator exposure. To apply water or chemicals with precision, it is necessary to determine the position of the irrigation system in the field with accuracy.

Approach

Computerized remote controls are being modified to allow determination of field position and automated control of devices for variable application of both water and chemicals on segments of the field irrigated by center pivot and linear move sprinklers. Application devices are being developed and evaluated for mounting on the sprinkler system to allow site specific applicaton.

Results

Computer remote controls and software developed by the team have been modified to control a linear move system. Existing control relays in the linear move control panel have been connected to a secondary controller which supervises variable applications. Remote control of these relays selects one of several preprogrammed patterns of applications. Pulsing of conventional irrigation sprinkler heads has been shown to be an effective method of reducing application depth from that determined by machine speed, with uniformities of 90% measured. Several methods of determining the position of the linear move sprinkler, including motor run timers, buried utility locators, and low cost GPS systems, have been installed and data collected during 1994. A unique, low cost chemical application system has been installed on one segment of the linear move, and uniformity tests are being evaluated.

Future plans

The pulse irrigation system will continue to be used to apply differential water treatments at the CSU ARDEC site for evaluation of long term performance. Several chemical application systems will be studied in the laboratory and installed on the linear move system for evaluation of practicality and performance when exposed to environmental variables. Computer software is being converted to the Windows environment for the CRADA sponsor. Evaluation of methods of locating the sprinkler in the field will continue, including use of differential GPS, with correction calculated by the base station computer to reduce costs.

[1]Valmont Industries, Valley, NE.

DEVELOP AN EVALUATION MODEL FOR CENTER PIVOT SYSTEMS

Author(s) D.F. Heermann, H.R. Duke, L. Dawson[1], and K. Admire[1]

Problem

Center pivot irrigation systems now irrigate approximately 25% of the total irrigated area in the United States. Center pivot manufacturers report that sales are very high which will increase the percentage of the irrigated area under center pivots. The conversion is to reduce labor requirements and irrigate land not suitable to surface methods. Increased efficiency is needed to reduce the environmental impact from irrigation. The NRCS (formerly SCS) has the need to perform evaluations of these systems. They currently are expending considerable effort in collecting field data for evaluating and recommending improvements. The current center pivot model appears to offer potential for decreasing the effort in evaluating these systems. A user friendly version of the simulation model provides the opportunity to evaluate the uniformity with less data collection. The model then can be used to evaluate the uniformity as well as test alternative system modifications before they are made.

Approach

A user friendly model will be developed for use by NRCS technicians and engineers. The model will provide for the entry of field catch can data as is now often collected for use in determining the irrigation uniformity. A pump test and inventory of the sprinkler heads, spacing, and pipe sizes of the system can served as input to the model and provide an alternative way of evaluating the system. The adoption of low pressure systems require an increased number of catch cans for an appropriate evaluation. This also makes it important to study the effect of start-stop of the towers which can reduce the uniformity. The first effort will be to investigate the errors introduced in the evaluation process when assuming the system is a continuous move without the start-stop of towers. The current integration technique requires extensive computation and simplifying techniques will be studied.

Results

A program has been written that can calculate the distribution of application depths with the input of start and stop times of individual towers. The data required for the simulation includes: pipe sizes, pump curve, sprinkler head spacing, sprinkler type, nozzle sizes, pattern shape, discharge coefficients, pressure regulators, and desired operating speeds. The simulation model has been validated with laboratory and field experimental data. It has sufficient agreement to provide valid estimates for evaluation and design.

Future plans

Simulation models will be developed to study different techniques for integrating the application depth of the moving system. The current model requires excessive calculations. The intent is to have a graphical interface to the model that is user friendly for use by field technicians and consultants. The intent is to add an analysis phase to the evaluation that provides specific recommendations for the irrigator when making modifications and for use in scheduling irrigations.

[1]Natural Resource Conservation Service, USDA.

SURFACE WATER REDISTRIBUTION UNDER MOVING SPRINKLERS

Author(s) D.F. Heermann, R.E. Smith, and P. Luz[1]

Problem

Sprinkler irrigation systems, especially high volume, low energy types, always have the possibility of applying water at a point at a rate higher than the infiltration capacity of the soil. Center pivot systems are designed to apply the same depth along the lateral. The application rate varies with distance from the pivot and with the type of sprinklers. Low pressure sprinklers have smaller pattern radii and higher application rates than higher pressure sprinklers. When the application rate exceeds the infiltration rate, the resulting runoff can have reduce the efficiency and decrease the water distribution uniformity, depending on the topography and amount and rate of runoff generated. Study of this problem requires the ability to calculate the infiltration from any application method, and model the movement of any generated surface water, where the slope of the soil may cause water to move in either or both directions down a furrow. Existing irrigation advance models are incapable of treating this more general case. Further, existing models are unable to properly treat cases where there may be a sequence of wetting and redistribution in the soil at any point. New tools are needed for the design and analysis of irrigation systems.

Approach

The application rate from moving systems will be simulated for the low and high pressure sprinkler patterns for input to the infiltration and surface flow models. The diffusive wave simplification of the general Saint Vennant equations for surface water flow allow for any reasonable positive slope, including flat surfaces, since the water surface slope is used rather than the bed slope. The numerical formulation can allow a negative slope as well, by using the slope sense to determine the direction of flow, and the absolute slope value within the expression itself. A robust and physically-derived infiltration model is used to solve for infiltration rates for intermittent application patterns, which includes redistribution calculations.

Results

Both diked and undiked, circular and linear furrows with point source application from a center pivot have been studied. Each has its advantages: the intermittent nature of the advance of a head on a center pivot system can cause local "dry" spots in the diked case, but the undiked furrows will as expected cause an excess at the low spots of the field. Data have been taken for variable advance rates at ARDEC, and more may be taken this year, to study both time and spatial variations in infiltration rates.

Future plans

An analysis of the detail needed to describe application rates under center pivots and resulting potential runoff will be made. The model will be developed with an algorithm that can determine a critical time step, to take advantage of conditions where longer time steps can be safely employed, and to prevent difficult iteration when smaller time steps are needed. An estimate of actual topography at the site of measured local application rates will allow completion of a case study for a paper on the model. Ultimately the model will be part of a larger, GIS-based simulation tool.

[1]Estacào Agronomica Nacional, Quinta do Marqués, Portugal

WATER MANAGEMENT WITH SPATIAL AND TEMPORAL VARIABILITY

Author(s) D.F. Heermann, M.J. Paulson[1], G.W. Buchleiter and W.C. Bausch

Problem

Production agriculture has become concerned about it's impact on the environment. Non-point pollution is a major factor contributing to decrease in water quality in both surface and ground water. The assumption that degradation occurs uniformly over large areas is not true. Prescription farming is an approach to reducing the chemicals in the environment practiced primarily on dry land farms. The solution to this problem under irrigated agriculture is an opportunity for the future. The systems designed for variable application of water and chemicals should reduce the environmental degradation. However, to implement this technology requires the assessment and characterization of the spatial variability. The use of geographical information systems (GIS) and global positioning systems (GPS) are tools that will allow the collection and analysis of spatial data. The layers of information collected over time will provide for analyzing the temporal variability.

Approach

The Agricultural Research, Demonstration and Education Center (ARDEC) at Colorado State University will provide the prototype area for developing GIS maps and collecting spatial data with sensors and GPS. The first task will be to develop the map of the area with bench mark control. Existing topographic, field physical boundaries, irrigation system and soils data bases will be put into ARC/INFO GIS program. Data will be collected from the current activities and procedures developed to input into the data base. The GPS will be used to position remote sensed data and other sampled data such as soil samples. The procedures to convert this data into the ARC/INFO data base will be developed. The data base will be used to analyze the spatial and temporal data.

Results

The construction drawings of ARDEC have been digitized and input to the ARC/INFO data base. The soils map layer has also been accomplished. The physical features of the field boundaries and irrigation system has been also digitized. A preliminary trial run for a procedure to input GPS remotely sensed data has been accomplished. It was found that there is significant differences between the GPS coordinate system and that from the construction drawings. Several bench marks have been established with the GPS system.

Future plans

Effort will continue in establishing additional bench marks and procedures for registering the GPS collected data with the ARC/INFO data base map. The map information will be used as input to the linear move irrigation system for applying variable water and chemicals. This will require mapping the desired applications into the control language of the irrigation system. An irrigation scheduling program will be developed that uses the variable information and allocates the water. Maps will be output to illustrate the required irrigations and the allocation of the available water supply. The procedures for overlaying and registering different maps of information will be developed.

[1]Dept. of Horticulture, Colo. State Univ.

IMPROVING WEED CONTROL AND WATER QUALITY WITH TILLAGE AND LESS HERBICIDE

Author(s) E.E. Schweizer, M. VanGessel[1], and P. Westra[1]

Problem

There are social and economic pressures for farmers to utilize weed management systems that reduce herbicide usage. Social pressures result from the use of herbicides in the environment and economic pressures result from the cost of herbicides, potential crop injury, and weeds becoming resistant to herbicides. Alachlor is a commonly used soil-applied herbicide in corn and has been detected in groundwater and surface water. Early-season weed control is important to minimize weed competition and improve crop yields. Historically, early season weed control research has focused on either soil-applied herbicides or use of tillage implements such as rotary hoes or cultivators. Innovative cultivators (i.e., in-row) designed to control weeds within the corn row may allow for less intensive pre-cultivation weed control (rotary hoeing). Thus, a 2-year field study was conducted in Colorado to determine the effectiveness of rotary hoeing, reduced soil-applied herbicide rates, and two types of cultivators to control annual weeds within the row in irrigated corn.

Approach

The efficacy of reduced alachlor rates to supplement or replace tillage at crop emergence and/or cultivation to control annual weeds was assessed in 1993 and 1994. Variables examined were: rate of alachlor (none, one-third (0.3X), and two-thirds (0.6X) of the labeled recommended rate); tillage at crop emergence (none, one or two passes with a rotary hoe); and cultivation (standard vs in-row cultivator). Weed management efficacy was determined in terms of weed control, crop grain yield, and gross margin (gross income minus weed control costs).

Results

Weed control with a single rotary hoeing at corn emergence controlled annual weeds similar to two rotary hoeings. Reduced rates (one third and two thirds) of alachlor controlled more weeds than rotary hoeing. The in-row cultivator was more efficient than the standard cultivator and required less intensive early-season weed control (rotary hoeing or reduced alachlor rate). When the spectrum of annual weeds is comprised of alachlor-susceptible species, a reduced rate of alachlor can adequately control these weeds while reducing costs and minimizing the risk of potential groundwater and surface water contamination. In the absence of alachlor, a rotary hoe is an integral part of a weed management strategy in conjunction with an in-row cultivator. Since rotary hoeing does not provide residual weed control, it must be done after weed seed germination but prior to seedling establishment. The in-row cultivator is a very effective weed management tool. In-row cultivation can provide corn producers with a level of weed control that may allow them to reduce the intensity of pre-cultivation weed control. Gross margin did not differ between treatments, which indicates that the additional weed control provided by the in-row cultivator did not reduce gross margin.

Future plans

Data from this two-year study has been analyzed and summarized and a manuscript was submitted to the *Agronomy Journal* in November.

[1]Dept. Plant Path. & Weed Sci., Colo. State Univ.

CHARACTERIZING WEED POPULATIONS IN NEBRASKA SOYBEAN FIELDS FOR MORE EFFICIENT MANAGEMENT

Author(s) D.A. Mortensen[1], L. J. Wiles, and E.E. Schweizer

Problem

Several herbicides are reaching groundwater and surface water from routine agricultural use. In the corn belt, soybean herbicides have been detected in groundwater and seasonally in surface water. More efficient management of weeds in soybean fields can enhance the quality of groundwater and surface water by reducing the use of herbicides.

Approach

Intensive field surveys were conducted in farmer's fields to determine the spatial distribution of composite broadleaf and grass weed seedlings in 13 corn and 12 soybean fields in eastern Nebraska in 1993 and 1994. Farmers had applied herbicides in a 15-inch band over 30-inch spaced rows. Two county extension agents and two crop consultants were involved in field selection and in coordinating follow-up visits to each site. Weed populations were determined in the interrow and band-treated intrarow. The weed population data was used to construct spatial maps that revealed the area occupied by weeds in each field.

Results

The spatial maps showed that grass and broadleaf weeds were not uniformly distributed throughout each field. Patchiness generally increased as weed density decreased. On average, 30% of the sample area in the 12 soybeans fields surveyed was free of broadleaf weeds and 70% free of grass weeds in the interrow area (area receiving no herbicide). Application of preemergence herbicides increased weed species patchiness. Where the preemergence herbicide was applied in the band, 71% of the sample area was free of broadleaf weeds and 94% free of grass weeds. The results of these distribution studies indicate that herbicide use could be substantially reduced if weed distribution maps or real-time plant sensing were available to provide information for applying herbicides only to those portions of fields where weeds are present.

Future plans

The field data is being used to evaluate several sampling strategies that could be used by crop consultants for weed scouting. Drs. Mortensen and Wiles will conduct additional simulation experiments to identify optimal scouting strategies and the value of the information obtained by scouting. Results from a survey of 60 crop consultants conducted in cooperation with the Nebraska Independent Crop Consultants Association will be summarized. The purpose of the survey was to provide information for researchers to better understand constraints to weed scouting faced by crop consultants. This Specific Cooperative Agreement is scheduled to terminate on September 1, 1995.

[1]Dept. Agronomy, Univ. Nebr.

PROTECTING WATER QUALITY BY SCOUTING WEED POPULATIONS

Author(s) L.J. Wiles and E.E. Schweizer

Problem

Weed control with herbicides is economic, convenient and effective. As a result, herbicides have lead the dramatic increase in the amount of pesticide applied. Approximately 70% of the total amount is applied to corn and soybean. Several herbicides are commonly detected in surface water and groundwater in the corn belt. Water quality could be enhanced by reducing the use of herbicides, and weed management could be more efficient if growers had more accurate, field-specific information about the composition and spatial distribution of weed populations. Thus, a 2-year field study was conducted in Colorado to develop scouting plans for obtaining the information about weed populations needed to use computer weed management models.

Approach

Weed seed bank and seedling populations were sampled in two pivot irrigated and two furrow irrigated commercial corn fields in eastern Colorado in 1994. These fields were different than those sampled in 1993. Before corn emergence, 1245 soil samples were collected on a square grid pattern in a 20-acre block. After corn emergence, weed seedlings were identified in a five foot length of crop row adjacent to each sample site. Time required for soil sampling and seedling counts was recorded.

Results

As in 1993, pigweed, lambsquarter, nightshade, foxtail and barnyardgrass were the most abundant seedling species. In addition, toothed spurge, wild buckwheat and buffalobur were prevalent. The time required to count and identify seedlings in a quadrat ranged from 15 seconds to almost five minutes. Weed seed counts have been completed for six fields (7470 samples). Preparing a sample for counting required about 5 minutes. Time required for identifying and counting the weed seeds varied with the amount of seed and sand in the sample. Based on the data analyzed so far, it appears that the negative binomial is a better model of the distribution of weed seeds than seedlings.

Future plans

The timetable for this research emphasized field sampling during the first two years and simulation experiments and publication of results during the final year. All of the field work has been completed as scheduled. Counting and identifying the seeds has been slower than expected as a result of the sandy soil and dense seed population of one field. All seed bank samples will be analyzed by February, 1995. Methodology and software for the simulation experiments and data analysis have been selected. The distributions of some seed and seedling populations have been analyzed and programming of the simulation models has been started.

GWM ---A DECISION AID FOR DRY BEAN PRODUCTION

Author(s) L.J. Wiles and E.E. Schweizer

Problem

Choosing the best way to manage weeds in fields is a complex, information- intensive task. Scientists have been developing decision support systems to help growers with this task. These systems predict the results of using different management strategies based on scientists' understanding of weed biology and ecology. Test results suggest that growers using these systems may get appropriate weed control with less herbicides. However, developing, programming, and maintaining such decision support systems is time-consuming and resource intensive.

Approach

A weed management decision support system, the General Weed Management Model (GWM), was designed with a general structure to allow use with different row crops. This microcomputer software package is for evaluating soil-applied and postemergence weed control strategies from estimates of the weed seed bank or seedling population in a field. The software includes a model which predicts biological and economic outcomes of using different management strategies. There is flexibility in how different biological processes may be represented within this model. The software also includes a database management module for entering, editing and reviewing model parameters, information on weed control treatments, data on farms and fields, and scouting information. The database management module can be used specify or adapt models for different crops or regions without programming.

Results

GWM has been parameterized for weed management decision support for irrigated corn and soybean production in Minnesota and dry bean production in Colorado, Wyoming and Nebraska. Another version has been set up to generate the predictions of WEEDCAM, a weed management decision support system for irrigated corn production in Colorado. The structure of the simulation model of GWM appears to be flexible enough to support weed management decisions in a variety of situations and the database management module facilitates specifying new models.

Future plans

The versions of GWM for weed management decision support in dry beans in Colorado, Nebraska, and Wyoming will be refined based on the results of field evaluations in 1993 and 1994. GWM will be distributed in 1995 through the University of Minnesota.

DEVELOPMENT OF A GENERAL, PHYSICALLY-BASED INFILTRATION-REDISTRIBUTION MODEL

Author(s) R.E. Smith, C.Corradini[1], and F. Melone[1]

Problem

Previous infiltration models have made assumptions of the rainfall pattern, generally, that it is always greater than capacity, or it is always less. Many rainfall events fail to meet this criteria, and at a point in an irrigated field, there may be a complex pattern of water application, including sprinkler input as well as flooded surface conditions. In addition, most existing infiltration models are quite inaccurate for very wet initial conditions, such as wil be the case after the first of a sequence of wetting events, or during surge irrigation. A model is needed which will reflect soil physical parameters and which will estimate intake rates for any pattern of rainfall rates at the surface, including estimation of the recovery of infiltration capacity for periods of no input, or low input rates.

Approach

A numerical solution of the dynamic equations for soil water flow was used as a robust model for the response of a soil profile to a variety of inputs, and results were compared with analytic approximations for the soil flow equations. One approximation was based on assuming the soil wetting profile to be an expanding shape with geometric similarity having a scalable shape factor. This assumption was useful for the case where the wetted profile is redistributing during periods of low or no rain. The method of Parlange (Parlange, et al., 1985) for periods of wetting prior to runoff was modified for use, and a new formulation of the 3 parameter infiltration model (Parlange et al.,1982) was developed to accurately model infiltration after a soil profile becomes wet (wet initial conditions). To characterize a given soil, the model requires very basic parameters to characterize a soil, including the saturated hydraulic conductivity, the parameter known as the effective capillary drive, the initial water deficit, and some estimate of the pore size distribution of the soil. This last value is measured by a pore-size distribution index, which is large for uniform particle sizes, ans small for soils with a large distribution of particle sizes.

Results

A series of tests on several soil types and several rather extreme cases was conducted, including a variety of patterns of rainfall rates, some having the potential to cause runoff, and some not. The worst cumulative error of the approximate model in comparison to the accurate solution was 11%, with typical errors on the order of 5%. The model can make infiltration estimates for conditions which are not possible with any other existing models, and can be used in conjuction with either rainfall/runoff models or with irrigation efficiency models.

Future plans

While the model is essentially complete, some additional work is being conducted to simplify prewetting estimation methods.

[1]IRPI, National Research Council, Perugia, Italy

DEVELOPMENT AND APPLICATION OF A DYNAMIC SOIL EROSION MODEL

Author(s) R.E. Smith, D.C. Goodrich[1], J.N. Quinton[2], and G. Govers[3]

Problem

Whenever there is water running on the soil surface, from whatever source, erosion of soil can be a problem. Soil erosion represents loss of nutrients, and an economic loss to farmers. This is a complex and difficult process to model, and prediction of erosion for a given flow, soil and topographic condition has been a source of study for some time. Recognizing the complexity of the phenomenon, almost all current methods are approximate, either by spatial or temporal lumping of variability, or by simply using regression estimates as is done in the USLE and RUSLE methods. There is a need to study the erosion process in its full dynamic, spatially variable condition, to develop better estimating models, and to evaluate the assumptions made by more approximate methods.

Approach

Erosion is considered, in our research, to be a transport process intimately linked to the conditions of flowing water and rainfall rate. As a transport process, there are fundamental relations of the transport capacity, the treatment of local input sources, and the functions of entrainment and deposition of material. The spatially distributed simulation of runoff velocities, depths, and slopes which are part of the kinematic wave runoff models such as KINEROS can be used directly to simulate spatially distributed values of entrained soil concentration. Rainfall energy at the soil surface is used to estimate the sediment dislodged by rainfall, and runoff models which include descriptions of plant and cobble cover can reflect their influence directly. Sediment transport capacity is considered a dynamic balance between continuous processes of erosion and deposition, simplifying the estimation of hydraulic processes.

Results

The basic dynamic, distributed erosion model is now a part of the model KINEROS and in modified form is incorporated in the European erosion model EUROSEM. Each has a somewhat different method of treating surface microtopography (rills and the role of rills in runoff, for example) and the effects of plant cover, and the estimation of transport capacity. The EUROSEM model has been extensively tested on plot studies throughout Europe, with general success. KINEROS has recently been used to show that there are significant weaknesses in the steady flow assumptions in the slope length factors in the WEPP and RUSLE models now in wide use.

Future plans

One future study will use all relevant existing experimental data to produce a single, best-fit relation for transport capacity of very shallow flows characteristic of runoff from rainfall or sprinkler irrigation. Almost all existing models use relations developed in flume studies that are rarely less than 10 cm in flow depth, whereas most surface flows are on the order of a few mm. Another area requiring further study is the distribution of transport energy among a range of particle sizes. Again, existing experimental data is for single particle size conditions in a flume. Joint work with CSU will be explored, in order to further our knowledge of particle size enrichment processes.

[1] ARS Southwest Watershed Research Center, Tucson, AZ. [2] Silsoe College, Silsoe, England. [3]Catholic University of Leuven, Leuven, Belgium

EFFECTIVE ENSEMBLE PROPERTIES OF A HETEROGENEOUS SOIL AREA

Author(s) R.E. Smith, B. Diekkrüger[1], and Y. Zhang

Problem

The application of physics of soil water flow has depended on the models and equations developed and tested on relatively homogeneous soil columns where conditions can be made simple for testing hypotheses, and demonstrating, for example, Darcy's Law. However, research continues to reveal the fact that for a large area, even where there is no observable change in soil type, soil properties are heterogeneous, and a certain amount of random variation is to be expected. Practical problems are almost always concerned with large areas which contain this heterogeneity, so a difficulty in application of soil physics, called "scaling up", must be addressed. This study attempts to assess the large scale behavior of a soil in terms of the vertical flow of water, treating the area as composed of an ensemble of a large number of samples.

Approach

Heterogeneity may have spatial dependence, and there may be a hierarchy of distributions depending on the scale of measurement. We confine this study to a soil with randomly varying parameter that describe the water retention and the conductivity curve. Measured data from an extensive sampling study in Germany and another in New Mexico is used to establish hypotheses concerning parameter distributions and independence, which allows simulations of the ensemble behavior. The ensemble (large scale) retention and conductivity curves (ψ-θ-K relations) can be established by simulation, given the sampling values of the distributions. A stratified sampling or multidimensional Latin Hypercube method is used with a numerical solution of Richards' equation to establish the relation of the ensemble dynamic behavior to that of a soil with the mean parameters, or a soil with the static ensemble characteristics.

Results

The observed relative independence of the soil retention parameters is in contrast to the usual assumption of similarity scaling to characterize soil random variation. At least for the soil data used here, similarity is not a supported assumption. The ensemble ψ-θ-K relations are shown to be biased with respect to the behavior of a sample with the mean parameters, as is expected for nonlinear functions. The effective dynamic ψ-θ-K relations are defined as those that reproduce the behavior of the ensemble under infiltration, and they have been shown to be unlike either the static ensemble ψ-θ-K relation or those of the mean parameters. This means that for any sample (even if small, such as a large soil core) the existence of heterogeneity will prevent the measurement of a ψ-θ-K relation that can be used to simulate flow processes. On the positive side, it has been shown that the ensemble or field average values of saturated water content and residual water content are applicable to dynamic simulations.

Future plans

An ongoing study is looking at the heterogeneity exhibited at the ARDEC experimental site, and the effect of heterogeneity on measurements of a disk permeameter. Further field measurements to characterize ARDEC random variations are the expected focus of future work.

[1]Inst. Für Geoökologie, Techn. Univ. Braunschweig, Germany

SIMULATION OF THE PRODUCTION AND LEACHING EFFECTS OF SOIL AND IRRIGATION VARIATIONS

Author(s) R.E. Smith, D. Santos[1]

Problem

Spatial variation of soils, water and fertilizer application amounts are realities that are currently causing research into "micro-management" of agricultural fields, so that better efficiency and uniformity of yield are obtained in light of soil and nutrient variations. Another important aim of current ideas for micro-management is the reduction in losses of chemicals to leaching below the root zone. For studies of micromanagement, the relation of application amounts, timing, fertilization scheduling, and local soil variations needs to be related to crop yield in a real climate pattern. This is a local agro-ecosystem modelling problem, and tools to apply on a site by site basis need to be applied to see the results of the range of variations of the above mentioned parameters.

Approach

The Opus model is already developed and is suitable for simulation for micro-management design. Field data gathered from the ARDEC test site give data on the expected variability of soil nitrogen in place, and soil property variations are also being measured. There are plot studies underway to look at various management options for N and water application for corn. The Opus model will be used along with weather records and the above listed data, to quantify the expected micro-variations in yield that can be expected. Part of this study will be a calibration, to insure that the model is reflecting the change in each variable reasonably well. An additional study using data gathered at an experimental site in Portugal will be undertaken.

Results

Data for crop and daily weather parameters for at lest two years have already been collected, as well as the soil N at the beginning and end of each crop year, plus a record of the management activity schedule. Yield and crop status data are also available to calibrate the corn growth model. Long term weather records are being collected and analyzed to obtain basic weather statistical parameters.

Future plans

Opus will be applied for several sites over the experimental area, representing measurement sites as well as sites with potentially most extreme combinations of N, water, and soil conditions, to obtain, after calibration, an idea of the range in local crop growth and yield that can be expected for the extent of variability on the ARDEC field site.

[1]Univ. Técnica de Lisboa, Lisbon, Portugal

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